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BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)
BACKGROUND DOCUMENT FOR
K022

(Non CBI Version)

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EXECUTIVE SUMMARY

BDAT Treatment Standards for K022

Pursuant to the Hazardous and Solid Waste Amendments (HSWA) enacted on November 8, 1984, the Environmental Protection Agency (EPA) is establishing best demonstrated available technology (BDAT) treatment standards for the listed waste identified in 40 CFR 261.32 as K022. Compliance with these BDAT treatment standards is a prerequisite for placement of the waste in units designated as land disposal units according to 40 CFR Part 268. The effective date of the nonwastewater standards is August 8, 1988. The applicability of the restrictions for K022 wastewater and the effective date are discussed in the preamble to the final rule for First Thirds wastes.

This background document provides the Agency's rationale and technical support for selecting the constituents to be regulated in nonwastewater forms of K022 waste and for developing treatment standards for those regulated constituents. The document also provides waste characterization information that serves as a basis for determining whether treatment variances may be warranted. EPA may grant a treatment variance in cases where the Agency determines that the waste in question is more difficult to treat than the waste upon which the treatment standards have been established.

The introductory section, which appears verbatim in all the First Third background documents, summarizes the Agency's legal authority and promulgated methodology for establishing treatment standards and discusses the petition process necessary for requesting a variance from the treatment standards. The remainder of the document presents waste-specific information--the number and locations of facilities affected by the land disposal restrictions for K022 waste, the waste-generating process, waste characterization data, the technologies used to treat the waste (or similar wastes), and available performance data, including data on which the treatment standards are based. The document also explains EPA's determination of BDAT, selection of constituents to be regulated, and calculation of treatment standards.

K022 waste is listed as "distillation bottom tars from the production of phenol/acetone from cumene." The Agency estimates that eight facilities produce phenol and acetone from cumene and thus generate K022 waste. These facilities fall under Standard Industrial Classification (SIC) Code 2869.

EPA is regulating five organic and two metal constituents in nonwastewater forms of K022 waste. (For the purpose of determining the applicability of the treatment standards, wastewaters are defined as wastes containing less than 1 percent (weight basis) total suspended solids* and less than 1 percent (weight basis) total organic carbon

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* The term "total suspended solids" (TSS) clarifies EPA's previously used terminology of "total solids" and "filterable solids." Specifically, total suspended solids is measured by method 209C (Total Suspended Solids Dried at 103-105°C) in _Standard Methods for the Examination of Water and Wastewater_, Sixteenth Edition.

(TOC). Waste not meeting this definition must comply with the treatment standards for nonwastewaters.) The nonwastewater treatment standards for the organic constituents are based on performance data from fuel substitution of K022 waste. The nonwastewater treatment standards for metals are based on performance data from stabilization.

Wastewater treatment standards for K022 are to be proposed and promulgated prior to May 8, 1990. Until this date, these wastes will be restricted from land disposal according to the provisions described in the preamble to the final rule for First Third wastes.

The following table lists the BDAT treatment standards for K022 nonwastewater. For BDAT list organics, the nonwastewater treatment standards reflect total constituent concentration; the units are mg/kg (parts per million on a weight-by-weight basis). For BDAT list metals in nonwastewater, treatment standards reflect leachate concentration from the toxicity characteristic leaching procedure (TCLP). The units are mg/l (parts per million on a weight-by-volume basis). Note that if the concentrations of the regulated constituents in the waste, as generated, are lower than or equal to the treatment standards, then treatment is not required prior to land disposal.

Testing procedures for all sample analyses performed for the regulated constituents are specifically identified in Appendix B of this background document.

EPA wishes to point out that because of facility claims of confidentiality, this document does not contain all of the data that EPA usually discloses in the documents supporting its decision-making process. In this document, the data restricted from public scrutiny pertain to data used for selecting constituents to regulate, data used for determining substantial treatment, and data used for developing BDAT treatment standards. Under 40 CFR Part 2, Subpart B, facilities may claim any or all of the data that are submitted to EPA as confidential business information (CBI). These confidentiality rules outline procedures that EPA must follow when using these data for rulemaking. Since EPA has not yet made a determination regarding the validity of the data being claimed as CBI, the data will be treated as CBI until a determination is made. The Agency would like to emphasize, however, that all the data have been evaluated according to the methodology presented in Section 1 of this document. All deletions of CBI are noted in the appropriate places.

BDAT Treatment Standards for K022

Constituent	Maximum for any single grab sample		
	Nonwastewater		Wastewater[a]
	Total concentration (mg/kg)	TCLP leachate concentration (mg/l)	Total concentration (mg/l)
Volatile Organics			
Toluene	0.034	NA	
Semivolatile Organics			
Acetophenone	19	NA	
Sum of Diphenylamine and Diphenylnitrosamine	13	NA	
Phenol	12	NA	
Metals			
Chromium (total)	NA	5.2	
Nickel	NA	0.32	

NA = Not applicable.

[a] EPA intends to propose and promulgate K022 wastewater treatment standards prior to May 8, 1990.

1. INTRODUCTION

This section of the background document presents a summary of the legal authority pursuant to which the best demonstrated available technology (BDAT) treatment standards were developed, a summary of EPA's promulgated methodology for developing the BDAT treatment standards, and, finally, a discussion of the petition process that should be followed to request a variance from the BDAT treatment standards.

1.1 Legal Background

1.1.1 Requirements Under HSWA

The Hazardous and Solid Waste Amendments of 1984 (HSWA), which were enacted on November 8, 1984, and which amended the Resource Conservation and Recovery Act of 1976 (RCRA), impose substantial new responsibilities on those who handle hazardous waste. In particular, the amendments require the Agency to promulgate regulations that restrict the land disposal of untreated hazardous wastes. In its enactment of HSWA, Congress stated explicitly that "reliance on land disposal should be minimized or eliminated, and land disposal, particularly landfill and surface impoundment, should be the least favored method for managing hazardous wastes" (RCRA section 1002(b)(7), 42 U.S.C. 6901(b)(7)).

One part of the amendments specifies dates on which particular groups of untreated hazardous wastes will be prohibited from land disposal unless "it has been demonstrated to the Administrator, to a reasonable degree of certainty, that there will be no migration of hazardous constituents from the disposal unit or injection zone for as long as the wastes remain hazardous" (RCRA section 3004(d)(1), (e)(1), (g)(5), 42 U.S.C. 6924 (d)(1), (e)(1), (g)(5)).

For the purpose of the restrictions, HSWA defines land disposal "to include, but not be limited to, any placement of . . . hazardous waste in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, or underground mine or cave" (RCRA section 3004(k), 42 U.S.C. 6924(k)). Although HSWA defines land disposal to include injection wells, such disposal of solvents, dioxins, and certain other wastes, known as the California List wastes, is covered on a separate schedule (RCRA section 3004(f)(2), 42 U.S.C. 6924 (f)(2)). This schedule requires that EPA develop land disposal restrictions for deep well injection by August 8, 1988.

The amendments also require the Agency to set "levels or methods of treatment, if any, which substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents from the waste so that short-term and long-term threats to human health and the environment are minimized" (RCRA section 3004(m)(1), 42 U.S.C. 6924 (m)(1)). Wastes that satisfy such levels or methods of treatment established by EPA, i.e., treatment standards, are not prohibited from being land disposed.

In setting treatment standards for listed or characteristic wastes, EPA may establish different standards for particular wastes within a single waste code with differing treatability characteristics. One such characteristic is the physical form of the waste. This frequently leads to different standards for wastewaters and nonwastewaters. Alternatively, EPA can establish a treatment standard that is applicable to more than one waste code when, in EPA's judgment, a particular constituent present in the wastes can be treated to the same concentration in all the wastes.

In those instances where a generator can demonstrate that the standard promulgated for the generator's waste cannot be achieved, the amendments allow the Agency to grant a variance from a treatment standard by revising the treatment standard for that particular waste through rulemaking procedures. (A further discussion of treatment variances is provided in Section 1.3.)

The land disposal restrictions are effective when promulgated unless the Administrator grants a national variance and establishes a different date (not to exceed 2 years beyond the statutory deadline) based on "the earliest date on which adequate alternative treatment, recovery, or disposal capacity which protects human health and the environment will be available" (RCRA section 3004(h)(2), 42 U.S.C. 6924 (h)(2)).

If EPA fails to set treatment standards by the statutory deadline for any hazardous waste in the First Third or Second Third waste groups (see Section 1.1.2), the waste may not be disposed in a landfill or surface impoundment unless the facility is in compliance with the minimum technological requirements specified in section 3004(o) of RCRA. In addition, prior to disposal, the generator must certify to the Administrator that the availability of treatment capacity has been investigated, and it has been determined that disposal in a landfill or surface impoundment is the only practical alternative to treatment currently available to the generator. This restriction on the use of landfills and surface impoundments applies until EPA sets treatment standards for the waste or until May 8, 1990, whichever is sooner. If the Agency fails to set treatment standards for any ranked hazardous waste by May 8, 1990, the waste is automatically prohibited from land disposal unless the waste is placed in a land disposal unit that is the subject of a successful "no migration" demonstration (RCRA section 3004(g), 42 U.S.C. 6924(g)). "No migration" demonstrations are based on case-specific petitions that show there will be no migration of hazardous constituents from the unit for as long as the waste remains hazardous.

1.1.2 Schedule for Developing Restrictions

Under section 3004(g) of RCRA, EPA was required to establish a schedule for developing treatment standards for all wastes that the Agency had listed as hazardous by November 8, 1984. Section 3004(g) required that this schedule consider the intrinsic hazards and volumes associated with each of these wastes. The statute required EPA to set treatment standards according to the following schedule:

1. Solvent and dioxin wastes by November 8, 1986;
2. The "California List" wastes by July 8, 1987;
3. At least one-third of all listed hazardous wastes by August 8, 1988 (First Third);

4. At least two-thirds of all listed hazardous wastes by June 8, 1989 (Second Third); and

5. All remaining listed hazardous wastes and all hazardous wastes identified as of November 8, 1984, by one or more of the characteristics defined in 40 CFR Part 261 by May 8, 1990 (Third Third).

The statute specifically identified the solvent wastes as those covered under waste codes F001, F002, F003, F004, and F005; it identified the dioxin-containing hazardous wastes as those covered under waste codes F020, F021, F022, and F023.

Wastes collectively known as the California List wastes, defined under section 3004(d) of HSWA, are liquid hazardous wastes containing metals, free cyanides, PCBs, corrosives (i.e., a pH less than or equal to 2.0), and any liquid or nonliquid hazardous waste containing halogenated organic compounds (HOCs) above 0.1 percent by weight. Rules for the California List were proposed on December 11, 1986, and final rules for PCBs, corrosives, and HOC-containing wastes were established August 12, 1987. In that rule, EPA elected not to establish treatment standards for metals. Therefore, the statutory limits became effective.

On May 28, 1986, EPA published a final rule (51 FR 19300) that delineated the specific waste codes that would be addressed by the First Third, Second Third, and Third Third land disposal restriction rules. This schedule is incorporated into 40 CFR 268.10, 268.11, and 268.12.

1.2 Summary of Promulgated BDAT Methodology

In a November 7, 1986, rulemaking, EPA promulgated a technology-based approach to establishing treatment standards under section 3004(m).

Congress indicated in the legislative history accompanying the HSWA that "[t]he requisite levels of [sic] methods of treatment established by the Agency should be the best that has been demonstrated to be achievable," noting that the intent is "to require utilization of available technology" and not a "process which contemplates technology-forcing standards" (Vol. 130 Cong. Rec. S9178 (daily ed., July 25, 1984)). EPA has interpreted this legislative history as suggesting that Congress considered the requirement under section 3004(m) to be met by application of the best demonstrated and achievable (i.e., available) technology prior to land disposal of wastes or treatment residuals. Accordingly, EPA's treatment standards are generally based on the performance of the best demonstrated available technology (BDAT) identified for treatment of the hazardous constituents. This approach involves the identification of potential treatment systems, the determination of whether they are demonstrated and available, and the collection of treatment data from well-designed and well-operated systems.

The treatment standards, according to the statute, can represent levels or methods of treatment, if any, that substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents. Wherever possible, the Agency prefers to establish BDAT treatment standards as "levels" of treatment (i.e., performance standards), rather than to require the use of specific treatment "methods." EPA believes that concentration-based treatment levels offer the regulated community greater flexibility to develop and implement compliance strategies, as well as an incentive to develop innovative technologies.

1.2.1 Waste Treatability Group

In developing the treatment standards, EPA first characterizes the waste(s). As necessary, EPA may establish treatability groups for wastes having similar physical and chemical properties. That is, if EPA believes that hazardous constituents in wastes represented by different waste codes could be treated to similar concentrations using identical technologies, the Agency combines the wastes into one treatability group. EPA generally considers wastes to be similar when they are both generated from the same industry and from similar processing stages. In addition, EPA may combine two or more separate wastes into the same treatability group when data are available showing that the waste characteristics affecting performance are similar or that one of the wastes in the group, the waste from which treatment standards are to be developed, is expected to be most difficult to treat.

Once the treatability groups have been established, EPA collects and analyzes data on identified technologies used to treat the wastes in each treatability group. The technologies evaluated must be demonstrated on the waste or a similar waste and must be available for use.

1.2.2 Demonstrated and Available Treatment Technologies

Consistent with legislative history, EPA considers demonstrated technologies to be those that are currently used on a full-scale basis to treat the waste of interest or a waste judged to be similar (see 51 FR 40588, November 7, 1986). EPA also will consider as demonstrated treatment those technologies used to separate or otherwise process chemicals and other materials on a full-scale basis. Some of these technologies clearly are applicable to waste treatment, since the wastes are similar to raw materials processed in industrial applications.

For most of the waste treatability groups for which EPA will promulgate treatment standards, EPA will identify demonstrated technologies either through review of literature related to current waste treatment practices or on the basis of information provided by specific facilities currently treating the waste or similar wastes.

In cases where the Agency does not identify any facilities treating wastes represented by a particular waste treatability group, EPA may transfer a finding of demonstrated treatment. To do this, EPA will compare the parameters affecting treatment selection for the waste treatability group of interest to other wastes for which demonstrated technologies already have been determined. (The parameters affecting treatment selection and their use for this waste are described in Section 3.2 of this document.) If the parameters affecting treatment selection are similar, then the Agency will consider the treatment technology also to be demonstrated for the waste of interest. For example, EPA considers rotary kiln incineration to be a demonstrated technology for many waste codes containing hazardous organic constituents, high total organic content, and high filterable solids content, regardless of whether any facility is currently treating these wastes. The basis for this determination is data found in literature and data generated by EPA confirming the use of rotary kiln incineration on wastes having the above characteristics.

If no full-scale treatment or recovery operations are identified for a waste or wastes with similar physical or chemical characteristics that affect treatment selection, the Agency will be unable to identify any demonstrated treatment technologies for the waste, and, accordingly, the waste will be prohibited from land disposal (unless handled in accordance with the exemption and variance provisions of the rule). The Agency is, however, committed to establishing treatment standards as soon as new or improved treatment processes are demonstrated (and available).

Operations only available at research facilities, pilot- and bench-scale operations, will not be considered in identifying demonstrated treatment technologies for a waste. Nevertheless, EPA may use data generated at research facilities in assessing the performance of demonstrated technologies.

As discussed earlier, Congress intended that technologies used to establish treatment standards under section 3004(m) be not only "demonstrated," but also "available." To decide whether demonstrated technologies may be considered "available," the Agency determines whether they (1) are commercially available and (2) substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents from the waste. These criteria are discussed below.

1. Commercially available treatment. If the demonstrated treatment technology is a proprietary or patented process that is not generally available, EPA will not consider the technology in its determination of the treatment standards. EPA will consider proprietary or patented processes available if it determines that the treatment method can be purchased or licensed from the proprietor or is a commercially available treatment. The services of the commercial facility offering this technology often can be purchased even if the technology itself cannot be purchased.

2. Substantial treatment. To be considered "available," a demonstrated treatment technology must "substantially diminish the toxicity" of the waste or "substantially reduce the likelihood of migration of hazardous constituents" from the waste in accordance with section 3004(m). By requiring that substantial treatment be achieved in order to set a treatment standard, the statute ensures that all wastes are adequately treated before being placed in or on the land and ensures that the Agency does not require a treatment method that provides little or no environmental benefit. Treatment will always be deemed substantial if it results in nondetectable levels of the hazardous constituents of concern (provided the nondetectable levels are low relative to the concentrations in the untreated waste). If nondetectable levels are not achieved, then a determination of substantial treatment will be made on a case-by-case basis. This approach is necessary because of the difficulty of establishing a meaningful guideline that can be applied broadly to the many wastes and technologies to be considered. EPA will consider the following factors in an effort to evaluate whether a technology provides substantial treatment on a case-by-case basis:

   - Number and types of constituents treated;
   - Performance (concentration of the constituents in the treatment residuals); and
   - Percent of constituents removed.

EPA will only set treatment standards based on a technology that meets both availability criteria. Thus, the decision to classify a technology as "unavailable" will have a direct impact on the treatment standard. If the best demonstrated technology is unavailable, the treatment standards will be based on the next best demonstrated treatment technology determined to be available. To the extent that the resulting treatment standards are less stringent, greater concentrations of hazardous constituents in the treatment residuals could be placed in land disposal units.

There also may be circumstances in which EPA concludes that for a given waste none of the demonstrated treatment technologies are "available" for purposes of establishing the 3004(m) treatment performance standards. Subsequently, these wastes will be prohibited from continued placement in or on the land unless managed in accordance with applicable exemptions and variance provisions. The Agency is, however, committed to establishing new treatment standards as soon as new or improved treatment processes become available.

1.2.3 Collection of Performance Data

Performance data on the demonstrated available technologies are evaluated by the Agency to determine whether the data are representative of well-designed and well-operated treatment systems. Only data from well-designed and well-operated systems are considered in determining BDAT. The data evaluation includes data already collected directly by

EPA and/or data provided by industry. In those instances where additional data are needed to supplement existing information, EPA collects additional data through a sampling and analysis program. The principal elements of this data collection program are: (1) the identification of facilities for site visits, (2) the engineering site visit, (3) the sampling and analysis plan, (4) the sampling visit, and (5) the onsite engineering report.

(1) Identification of facilities for site visits. To identify facilities that generate and/or treat the waste of concern, EPA uses a number of information sources. These include Stanford Research Institute's Directory of Chemical Producers; EPA's Hazardous Waste Data Management System (HWDMS); the 1986 Treatment, Storage, Disposal Facility (TSDF) National Screening Survey; and EPA's Industry Studies Data Base. In addition, EPA contacts trade associations to inform them that the Agency is considering visits to facilities in their industry and to solicit their assistance in identifying facilities for EPA to consider in its treatment sampling program.

After identifying facilities that treat the waste, EPA uses this hierarchy to select sites for engineering visits: (1) generators treating single wastes on site; (2) generators treating multiple wastes together on site; (3) commercial treatment, storage, and disposal facilities (TSDFs); and (4) EPA in-house treatment. This hierarchy is based on two concepts: (1) to the extent possible, EPA should develop treatment standards from data produced by treatment facilities handling only a single waste, and (2) facilities that routinely treat a specific waste have had the best opportunity to optimize design parameters. Although excellent treatment can occur at many facilities that are not high in this hierarchy, EPA has adopted this approach to avoid, when possible, ambiguities related to the mixing of wastes before and during treatment.

When possible, the Agency will evaluate treatment technologies using full-scale treatment systems. If performance data from properly designed and operated full-scale systems treating a particular waste or a waste judged to be similar are not available, EPA may use data from research facility operations. Whenever research facility data are used, EPA will explain in the preamble and background document why such data were used and will request comments on the use of such data.

Although EPA's data bases provide information on treatment for individual wastes, the data bases rarely provide data that support the selection of one facility for sampling over another. In cases where several treatment sites appear to fall into the same level of the hierarchy, EPA selects sites for visits strictly on the basis of which facility could most expeditiously be visited and later sampled if justified by the engineering visit.

(2) Engineering site visit. Once a treatment facility has been selected, an engineering site visit is made to confirm that a candidate for sampling meets EPA's criteria for a well-designed facility and to

ensure that the necessary sampling points can be accessed to determine operating parameters and treatment effectiveness. During the visit, EPA also confirms that the facility appears to be well operated, although the actual operation of the treatment system during sampling is the basis for EPA's decisions regarding proper operation of the treatment unit. In general, the Agency considers a well-designed facility to be one that contains the unit operations necessary to treat the various hazardous constituents of the waste, as well as to control other nonhazardous materials in the waste that may affect treatment performance.

In addition to ensuring that a system is reasonably well designed, the engineering visit examines whether the facility has a way to measure the operating parameters that affect performance of the treatment system during the waste treatment period. For example, EPA may choose not to sample a treatment system that operates in a continuous mode, for which an important operating parameter cannot be continuously recorded. In such systems, instrumentation is important in determining whether the treatment system is operating at design values during the waste treatment period.

(3) Sampling and analysis plan. If after the engineering site visit the Agency decides to sample a particular plant, the Agency will then develop a site-specific sampling and analysis plan (SAP) according to the Generic Quality Assurance Project Plan for the Land Disposal Restrictions Program ("BDAT"), EPA/530-SW-87-011. In brief, the SAP discusses where the Agency plans to sample, how the samples will be taken, the frequency

of sampling, the constituents to be analyzed and the method of analysis, operational parameters to be obtained, and specific laboratory quality control checks on the analytical results.

The Agency will generally produce a draft of the site-specific SAP within 2 to 3 weeks of the engineering visit. The draft of the SAP is then sent to the plant for review and comment. With few exceptions, the draft SAP should be a confirmation of data collection activities discussed with the plant personnel during the engineering site visit. EPA encourages plant personnel to recommend any modifications to the SAP that they believe will improve the quality of the data.

It is important to note that sampling of a plant by EPA does not mean that the data will be used in the development of BDAT treatment standards. EPA's final decision on whether to use data from a sampled plant depends on the actual analysis of the waste being treated and on the operating conditions at the time of sampling. Although EPA would not plan to sample a facility that was not ostensibly well designed and well operated, there is no way to ensure that at the time of the sampling the facility will not experience operating problems. Additionally, EPA statistically compares its test data to suitable industry-provided data, where available, in its determination of what data to use in developing treatment standards. The methodology for comparing data is presented later in this section.

(Note: Facilities wishing to submit data for consideration in the development of BDAT standards should, to the extent possible, provide sampling information similar to that acquired by EPA. Such facilities should review the Generic Quality Assurance Project Plan for the Land Disposal Restrictions Program ("BDAT"), which delineates all of the quality control and quality assurance measures associated with sampling and analysis. Quality assurance and quality control procedures are summarized in Section 1.2.6 of this document.)

(4) Sampling visit. The purpose of the sampling visit is to collect samples that characterize the performance of the treatment system and to document the operating conditions that existed during the waste treatment period. At a minimum, the Agency attempts to collect sufficient samples of the untreated waste and solid and liquid treatment residuals so that variability in the treatment process can be accounted for in the development of the treatment standards. To the extent practicable, and within safety constraints, EPA or its contractors collect all samples and ensure that chain-of-custody procedures are conducted so that the integrity of the data is maintained.

In general, the samples collected during the sampling visit will have already been specified in the SAP. In some instances, however, EPA will not be able to collect all planned samples because of changes in the facility operation or plant upsets; EPA will explain any such deviations from the SAP in its follow-up onsite engineering report.

(5) Onsite engineering report. EPA summarizes all its data collection activities and associated analytical results for testing at a facility in a report referred to as the onsite engineering report (OER). This report characterizes the waste(s) treated, the treated residual concentrations, the design and operating data, and all analytical results including methods used and accuracy results. This report also describes any deviations from EPA's suggested analytical methods for hazardous wastes that appear in Test Methods for Evaluating Solid Waste, SW-846, Third Edition, November 1986.

After the OER is completed, the report is submitted to the waste generator and/or treater for review. This review provides a final opportunity for claiming any information contained in the report as confidential. Following the review and incorporation of comments, as appropriate, the report is made available to the public with the exception of any material claimed as confidential.

1.2.4 Hazardous Constituents Considered and Selected for Regulation

(1) Development of BDAT list. The list of hazardous constituents within the waste codes that are targeted for treatment is referred to by the Agency as the BDAT constituent list. This list, provided as Table 1-1, is derived from the constituents presented in 40 CFR Part 261, Appendices VII and VIII, as well as several ignitable constituents used as the basis of listing wastes as F003 and F005. These sources provide a

Table 1-1 BDAT Constituent List

BDAT reference no.	Constituent	CAS no.
	Volatile organics	
222.	Acetone	67-64-1
1.	Acetonitrile	75-05-8
2.	Acrolein	107-02-8
3.	Acrylonitrile	107-13-1
4.	Benzene	71-43-2
5.	Bromodichloromethane	75-27-4
6.	Bromomethane	74-83-9
223.	n-Butyl alcohol	71-36-3
7.	Carbon tetrachloride	56-23-5
8.	Carbon disulfide	75-15-0
9.	Chlorobenzene	108-90-7
10.	2-Chloro-1,3-butadiene	126-99-8
11.	Chlorodibromomethane	124-48-1
12.	Chloroethane	75-00-3
13.	2-Chloroethyl vinyl ether	110-75-8
14.	Chloroform	67-66-3
15.	Chloromethane	74-87-3
16.	3-Chloropropene	107-05-1
17.	1,2-Dibromo-3-chloropropane	96-12-8
18.	1,2-Dibromoethane	106-93-4
19.	Dibromomethane	74-95-3
20.	trans-1,4-Dichloro-2-butene	110-57-6
21.	Dichlorodifluoromethane	75-71-8
22.	1,1-Dichloroethane	75-34-3
23.	1,2-Dichloroethane	107-06-2
24.	1,1-Dichloroethylene	75-35-4
25.	trans-1,2-Dichloroethene	156-60-5
26.	1,2-Dichloropropane	78-87-5
27.	trans-1,3-Dichloropropene	10061-02-6
28.	cis-1,3-Dichloropropene	10061-01-5
29.	1,4-Dioxane	123-91-1
224.	2-Ethoxyethanol	110-80-5
225.	Ethyl acetate	141-78-6
226.	Ethyl benzene	100-41-4
30.	Ethyl cyanide	107-12-0
227.	Ethyl ether	60-29-7
31.	Ethyl methacrylate	97-63-2
214.	Ethylene oxide	75-21-8
32.	Iodomethane	74-88-4
33.	Isobutyl alcohol	78-83-1
228.	Methanol	67-56-1
34.	Methyl ethyl ketone	78-93-3

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Volatile organics (continued)	
229.	Methyl isobutyl ketone	108-10-1
35.	Methyl methacrylate	80-62-6
37.	Methacrylonitrile	126-98-7
38.	Methylene chloride	75-09-2
230.	2-Nitropropane	79-46-9
39.	Pyridine	110-86-1
40.	1,1,1,2-Tetrachloroethane	630-20-6
41.	1,1,2,2-Tetrachloroethane	79-34-6
42.	Tetrachloroethene	127-18-4
43.	Toluene	108-88-3
44.	Tribromomethane	75-25-2
45.	1,1,1-Trichloroethane	71-55-6
46.	1,1,2-Trichloroethane	79-00-5
47.	Trichloroethene	79-01-6
48.	Trichloromonofluoromethane	75-69-4
49.	1,2,3-Trichloropropane	96-18-4
231.	1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1
50.	Vinyl chloride	75-01-4
215.	1,2-Xylene	97-47-6
216.	1,3-Xylene	108-38-3
217.	1,4 Xylene	106-44-5
	Semivolatile organics	
51.	Acenaphthalene	208-96-8
52.	Acenaphthene	83-32-9
53.	Acetophenone	96-86-2
54.	2-Acetylaminofluorene	53-96-3
55.	4-Aminobiphenyl	92-67-1
56.	Aniline	62-53-3
57.	Anthracene	120-12-7
58.	Aramite	140-57-8
59.	Benz(a)anthracene	56-55-3
218.	Benzal chloride	98-87-3
60.	Benzenethiol	108-98-5
61.	Deleted	
62.	Benzo(a)pyrene	50-32-8
63.	Benzo(b)fluoranthene	205-99-2
64.	Benzo(ghi)perylene	191-24-2
65.	Benzo(k)fluoranthene	207-08-9
66.	p-Benzoquinone	106-51-4

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
67.	Bis(2-chloroethoxy)methane	111-91-1
68.	Bis(2-chloroethyl)ether	111-44-4
69.	Bis(2-chloroisopropyl)ether	39638-32-9
70.	Bis(2-ethylhexyl)phthalate	117-81-7
71.	4-Bromophenyl phenyl ether	101-55-3
72.	Butyl benzyl phthalate	85-68-7
73.	2-sec-Butyl-4,6-dinitrophenol	88-85-7
74.	p-Chloroaniline	106-47-8
75.	Chlorobenzilate	510-15-6
76.	p-Chloro-m-cresol	59-50-7
77.	2-Chloronaphthalene	91-58-7
78.	2-Chlorophenol	95-57-8
79.	3-Chloropropionitrile	542-76-7
80.	Chrysene	218-01-9
81.	ortho-Cresol	95-48-7
82.	para-Cresol	106-44-5
232.	Cyclohexanone	108-94-1
83.	Dibenz(a,h)anthracene	53-70-3
84.	Dibenzo(a,e)pyrene	192-65-4
85.	Dibenzo(a,i)pyrene	189-55-9
86.	m-Dichlorobenzene	541-73-1
87.	o-Dichlorobenzene	95-50-1
88.	p-Dichlorobenzene	106-46-7
89.	3,3'-Dichlorobenzidine	91-94-1
90.	2,4-Dichlorophenol	120-83-2
91.	2,6-Dichlorophenol	87-65-0
92.	Diethyl phthalate	84-66-2
93.	3,3'-Dimethoxybenzidine	119-90-4
94.	p-Dimethylaminoazobenzene	60-11-7
95.	3,3'-Dimethylbenzidine	119-93-7
96.	2,4-Dimethylphenol	105-67-9
97.	Dimethyl phthalate	131-11-3
98.	Di-n-butyl phthalate	84-74-2
99.	1,4-Dinitrobenzene	100-25-4
100.	4,6-Dinitro-o-cresol	534-52-1
101.	2,4-Dinitrophenol	51-28-5
102.	2,4-Dinitrotoluene	121-14-2
103.	2,6-Dinitrotoluene	606-20-2
104.	Di-n-octyl phthalate	117-84-0
105.	Di-n-propylnitrosamine	621-64-7
106.	Diphenylamine	122-39-4
219.	Diphenylnitrosamine	86-30-6

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
107.	1,2-Diphenylhydrazine	122-66-7
108.	Fluoranthene	206-44-0
109.	Fluorene	86-73-7
110.	Hexachlorobenzene	118-74-1
111.	Hexachlorobutadiene	87-68-3
112.	Hexachlorocyclopentadiene	77-47-4
113.	Hexachloroethane	67-72-1
114.	Hexachlorophene	70-30-4
115.	Hexachloropropene	1888-71-7
116.	Indeno(1,2,3-cd)pyrene	193-39-5
117.	Isosafrole	120-58-1
118.	Methapyrilene	91-80-5
119.	3-Methylcholanthrene	56-49-5
120.	4,4'-Methylenebis (2-chloroaniline)	101-14-4
36.	Methyl methanesulfonate	66-27-3
121.	Naphthalene	91-20-3
122.	1,4-Naphthoquinone	130-15-4
123.	1-Naphthylamine	134-32-7
124.	2-Naphthylamine	91-59-8
125.	p-Nitroaniline	100-01-6
126.	Nitrobenzene	98-95-3
127.	4-Nitrophenol	100-02-7
128.	N-Nitrosodi-n-butylamine	924-16-3
129.	N-Nitrosodiethylamine	55-18-5
130.	N-Nitrosodimethylamine	62-75-9
131.	N-Nitrosomethylethylamine	10595-95-6
132.	N-Nitrosomorpholine	59-89-2
133.	N-Nitrosopiperidine	100-75-4
134.	N-Nitrosopyrrolidine	930-55-2
135.	5-Nitro-o-toluidine	99-65-8
136.	Pentachlorobenzene	608-93-5
137.	Pentachloroethane	76-01-7
138.	Pentachloronitrobenzene	82-68-8
139.	Pentachlorophenol	87-86-5
140.	Phenacetin	62-44-2
141.	Phenanthrene	85-01-8
142.	Phenol	108-95-2
220.	Phthalic anhydride	85-44-9
143.	2-Picoline	109-06-8
144.	Pronamide	23950-58-5
145.	Pyrene	129-00-0
146.	Resorcinol	108-46-3

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
147.	Safrole	94-59-7
148.	1,2,4,5-Tetrachlorobenzene	95-94-3
149.	2,3,4,6-Tetrachlorophenol	58-90-2
150.	1,2,4-Trichlorobenzene	120-82-1
151.	2,4,5-Trichlorophenol	95-95-4
152.	2,4,6-Trichlorophenol	88-06-2
153.	Tris(2,3-dibromopropyl) phosphate	126-72-7
	Metals	
154.	Antimony	7440-36-0
155.	Arsenic	7440-38-2
156.	Barium	7440-39-3
157.	Beryllium	7440-41-7
158.	Cadmium	7440-43-9
159.	Chromium (total)	7440-47-3
221.	Chromium (hexavalent)	-
160.	Copper	7440-50-8
161.	Lead	7439-92-1
162.	Mercury	7439-97-6
163.	Nickel	7440-02-0
164.	Selenium	7782-49-2
165.	Silver	7440-22-4
166.	Thallium	7440-28-0
167.	Vanadium	7440-62-2
168.	Zinc	7440-66-6
	Inorganics other than metals	
169.	Cyanide	57-12-5
170.	Fluoride	16964-48-8
171.	Sulfide	8496-25-8
	Organochlorine pesticides	
172.	Aldrin	309-00-2
173.	alpha-BHC	319-84-6
174.	beta-BHC	319-85-7
175.	delta-BHC	319-86-8

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Organochlorine pesticides (continued)	
176.	gamma-BHC	58-89-9
177.	Chlordane	57-74-9
178.	DDD	72-54-8
179.	DDE	72-55-9
180.	DDT	50-29-3
181.	Dieldrin	60-57-1
182.	Endosulfan I	939-98-8
183.	Endosulfan II	33213-6-5
184.	Endrin	72-20-8
185.	Endrin aldehyde	7421-93-4
186.	Heptachlor	76-44-8
187.	Heptachlor epoxide	1024-57-3
188.	Isodrin	465-73-6
189.	Kepone	143-50-0
190.	Methoxyclor	72-43-5
191.	Toxaphene	8001-35-2
	Phenoxyacetic acid herbicides	
192.	2,4-Dichlorophenoxyacetic acid	94-75-7
193.	Silvex	93-72-1
194.	2,4,5-T	93-76-5
	Organophosphorous insecticides	
195.	Disulfoton	298-04-4
196.	Famphur	52-85-7
197.	Methyl parathion	298-00-0
198.	Parathion	56-38-2
199.	Phorate	298-02-2
	PCBs	
200.	Aroclor 1016	12674-11-2
201.	Aroclor 1221	11104 28-2
202.	Aroclor 1232	11141-16-5
203.	Aroclor 1242	53469-21-9
204.	Aroclor 1248	12672-29-6
205.	Aroclor 1254	11097-69-1
206.	Aroclor 1260	11096-82-5

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Dioxins and furans	
207.	Hexachlorodibenzo-p-dioxins	-
208.	Hexachlorodibenzofurans	-
209.	Pentachlorodibenzo-p-dioxins	-
210.	Pentachlorodibenzofurans	-
211.	Tetrachlorodibenzo-p-dioxins	-
212.	Tetrachlorodibenzofurans	-
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6

comprehensive list of hazardous constituents specifically regulated under RCRA. The BDAT list consists of those constituents that can be analyzed using methods published in SW-846, Third Edition.

The initial BDAT constituent list was published in EPA's Generic Quality Assurance Project Plan for Land Disposal Restrictions Program ("BDAT") in March 1987. Additional constituents are added to the BDAT constituent list as more key constituents are identified for specific waste codes or as new analytical methods are developed for hazardous constituents. For example, since the list was published in March 1987, 18 additional constituents (hexavalent chromium, xylenes (all three isomers), benzal chloride, phthalic anhydride, ethylene oxide, acetone, n-butyl alcohol, 2-ethoxyethanol, ethyl acetate, ethyl benzene, ethyl ether, methanol, methyl isobutyl ketone, 2-nitropropane, 1,1,2-trichloro-1,2,2-trifluoroethane, and cyclohexanone) have been added to the list.

Chemicals are listed in Appendix VIII if they are shown in scientific studies to have toxic, carcinogenic, mutagenic, or teratogenic effects on humans or other life-forms, and they include such substances as those identified by the Agency's Carcinogen Assessment Group as being carcinogenic. A waste can be listed as a toxic waste on the basis that it contains a constituent in Appendix VIII.

Although Appendix VII, Appendix VIII, and the F003 and F005 ignitables provide a comprehensive list of RCRA-regulated hazardous constituents, not all of the constituents can be analyzed in a complex waste matrix. Therefore, constituents that could not be readily analyzed in an unknown waste matrix were not included on the initial BDAT constituent list. As mentioned above, however, the BDAT constituent list is a continuously growing list that does not preclude the addition of new constituents when analytical methods are developed.

There are five major reasons that constituents were not included on the BDAT constituent list:

1. Constituents are unstable. Based on their chemical structure, some constituents will either decompose in water or will ionize. For example, maleic anhydride will form maleic acid when it comes in contact with water, and copper cyanide will ionize to form copper and cyanide ions. However, EPA may choose to regulate the decomposition or ionization products.

2. EPA-approved or verified analytical methods are not available. Many constituents, such as 1,3,5-trinitrobenzene, are not measured adequately or even detected using any of EPA's analytical methods published in SW-846 Third Edition.

3. The constituent is a member of a chemical group designated in Appendix VIII as not otherwise specified (N.O.S.). Constituents listed as N.O.S., such as chlorinated phenols, are a generic group of some types of chemicals for which a single analytical procedure is not available. The individual members of each such group need to be listed to determine whether the constituents can be analyzed. For each N.O.S. group, all those constituents that can be readily analyzed are included in the BDAT constituent list.

4. Available analytical procedures are not appropriate for a complex waste matrix. Some compounds, such as auramine, can be analyzed as a pure constituent. However, in the presence of other constituents, the recommended analytical method does not positively identify the constituent. The use of high performance liquid chromatography (HPLC) presupposes a high expectation of finding the specific constituents of interest. In using this procedure to screen samples, protocols would have to be developed on a case-specific basis to verify the identity of constituents present in the samples. Therefore, HPLC is usually not an appropriate analytical procedure for complex samples containing unknown constituents.

5. Standards for analytical instrument calibration are not commercially available. For several constituents, such as benz(c)acridine, commercially available standards of a "reasonably" pure grade are not available. The unavailability of a standard was determined by a review of catalogs from specialty chemical manufacturers.

Two constituents (fluoride and sulfide) are not specifically included in Appendices VII and VIII; however, these compounds are included on the BDAT list as indicator constituents for compounds from Appendices VII and VIII such as hydrogen fluoride and hydrogen sulfide, which ionize in water.

The BDAT constituent list presented in Table 1-1 is divided into the following nine groups:

- Volatile organics;
- Semivolatile organics;
- Metals;
- Other inorganics;
- Organochlorine pesticides;
- Phenoxyacetic acid herbicides;
- Organophosphorous insecticides;
- PCBs; and
- Dioxins and furans.

The constituents were placed in these categories based on their chemical properties. The constituents in each group are expected to behave similarly during treatment and are also analyzed, with the exception of the metals and the other inorganics, by using the same analytical methods.

(2) Constituent selection analysis. The constituents that the Agency selects for regulation in each waste are, in general, those found in the untreated wastes at treatable concentrations. For certain waste

codes, the target list for the untreated waste may have been shortened (relative to analyses performed to test treatment technologies) because of the extreme unlikelihood that the constituent will be present.

In selecting constituents for regulation, the first step is to develop of list of potentially regulated constituents by summarizing all the constituents that are present or are likely to be present in the untreated waste at treatable concentrations. A constituent is considered present in a waste if the constituent (1) is detected in the untreated waste above the detection limit, (2) is detected in any of the treated residuals above the detection limit, or (3) is likely to be present based on the Agency's analyses of the waste-generating process. In case (2), the presence of other constituents in the untreated waste may interfere with the quantification of the constituent of concern, making the detection limit relatively high and resulting in a finding of "not detected" when, in fact, the constituent is present in the waste. Thus, the Agency reserves the right to regulate such constituents.

After developing a list of potential constituents for regulation. EPA reviews this list to determine if any of these constituents can be excluded from regulation because they would be controlled by regulation of other constituents on the list. This indicator analysis is done for two reasons: (1) it reduces the analytical cost burdens on the treater and (2) it facilitates implementation of the compliance and enforcement program. EPA's rationale for selection of regulated constituents for this waste code is presented in Section 6 of this background document.

(3) Calculation of standards. The final step in the calculation of the BDAT treatment standard is the multiplication of the average accuracy-corrected treatment value by a factor referred to by the Agency as the variability factor. This calculation takes into account that even well-designed and well-operated treatment systems will experience some fluctuations in performance. EPA expects that fluctuations will result from inherent mechanical limitations in treatment control systems, collection of treated samples, and analysis of these samples. All of the above fluctuations can be expected to occur at well-designed and well-operated treatment facilities. Therefore, setting treatment standards utilizing a variability factor should be viewed not as a relaxing of section 3004(m) requirements, but rather as a function of the normal variability of the treatment processes. A treatment facility will have to be designed to meet the mean achievable treatment performance level to ensure that the performance levels remain within the limits of the treatment standard.

The Agency calculates a variability factor for each constituent of concern within a waste treatability group using the statistical calculation presented in Appendix A. The equation for calculating the variability factor is the same as that used by EPA for the development of numerous regulations in the Effluent Guidelines Program under the Clean Water Act. The variability factor establishes the instantaneous maximum based on the 99th percentile value.

There is an additional step in the calculation of the treatment standards in those instances where the ANOVA analysis shows that more than one technology achieves a level of performance that represents BDAT. In such instances, the BDAT treatment standard for each constituent of concern is calculated by first averaging the mean performance value for each technology and then multiplying that value by the highest variability factor among the technologies considered. This procedure ensures that all the technologies used as the basis for the BDAT treatment standards will achieve full compliance.

1.2.5 Compliance with Performance Standards

Usually the treatment standards reflect performance achieved by the best demonstrated available technology (BDAT). As such, compliance with these numerical standards requires only that the treatment level be achieved prior to land disposal. It does not require the use of any particular treatment technology. While dilution of the waste as a means to comply with the standards is prohibited, wastes that are generated in such a way as to naturally meet the standards can be land disposed without treatment. With the exception of treatment standards that prohibit land disposal or that specify use of certain treatment methods, all established treatment standards are expressed as concentration levels.

EPA is using both the total constituent concentration and the concentration of the constituent in the TCLP extract of the treated waste as a measure of technology performance.

For all organic constituents, EPA is basing the treatment standards on the total constituent concentration found in the treated waste. EPA is using this measurement because most technologies for treatment of organics destroy or remove organics compounds. Accordingly, the best measure of performance would be the total amount of constituent remaining after treatment. (NOTE: EPA's land disposal restrictions for solvent waste codes F001-F005 (51 FR 40572) use the TCLP extract value as a measure of performance. At the time that EPA promulgated the treatment standards for F001-F005, useful data were not available on total constituent concentrations in treated residuals, and, as a result, the TCLP data were considered to be the best measure of performance.)

For all metal constituents, EPA is using both total constituent concentration and/or the TCLP extract concentration as the basis for treatment standards. The total constituent concentration is being used when the technology basis includes a metal recovery operation. The underlying principle of metal recovery is that it reduces the amount of metal in a waste by separating the metal for recovery; total constituent concentration in the treated residual, therefore, is an important measure of performance for this technology. Additionally, EPA also believes that it is important that any remaining metal in a treated residual waste not be in a state that is easily leachable; accordingly, EPA is also using the TCLP extract concentration as a measure of performance. It is important to note that for wastes for which treatment standards are based on a metal recovery process, the facility has to comply with both the total and the TCLP extract constituent concentrations prior to land disposing the waste.

In cases where treatment standards for metals are not based on recovery techniques but rather on stabilization, EPA is using only the TCLP value as a measure of performance. The Agency's rationale is that stabilization is not meant to reduce the concentration of metal in a waste but only to chemically minimize the ability of the metal to leach.

1.2.6 Identification of BDAT

BDAT for a waste must be the "best" of the demonstrated available technologies. EPA determines which technology constitutes "best" after screening the available data from each demonstrated technology, adjusting these data for accuracy, and comparing the performance of each demonstrated technology to that of the others. If only one technology is identified as demonstrated, it is considered "best"; if it is available, the technology is BDAT.

(1) Screening of treatment data. The first activity in determining which of the treatment technologies represent treatment by BDAT is to screen the treatment performance data from each of the demonstrated and available technologies according to the following criteria:

1. Design and operating data associated with the treatment data must reflect a well-designed, well-operated system for each treatment data point. (The specific design and operating parameters for each demonstrated technology for the waste code(s) of interest are discussed in Section 3.2 of this document.)

2. Sufficient QA/QC data must be available to determine the true values of the data from the treated waste. This screening criterion involves adjustment of treated data to take into account that the true value may be different from the measured value. This discrepancy generally is caused by other constituents in the waste that can mask results or otherwise interfere with the analysis of the constituent of concern.

3. The measure of performance must be consistent with EPA's approach to evaluating treatment by type of constituents (e.g., total concentration data for organics, and total concentration and TCLP extract concentration for metals from the residual).

In the absence of data needed to perform the screening analysis, EPA will make decisions on a case-by-case basis as to whether to use the data as a basis for the treatment standards. The factors included in this case-by-case analysis will be the actual treatment levels achieved, the availability of the treatment data and their completeness (with respect to the above criteria), and EPA's assessment of whether the untreated waste represents the waste code of concern.

(2) Comparison of treatment data. In cases in which EPA has treatment data from more than one demonstrated available technology following the screening activity, EPA uses the statistical method known as analysis of variance (ANOVA) to determine if one technology performs significantly better than the others. This statistical method (summarized in Appendix A) provides a measure of the differences between two data sets. Specifically, EPA uses the analysis of variance to determine whether BDAT represents a level of performance achieved by only one technology or represents a level of performance achieved by more than one (or all) of the technologies. If EPA finds that one technology performs significantly better (i.e., is "best"), BDAT treatment standards

are the level of performance achieved by that best technology multiplied by the corresponding variability factor for each regulated constituent. If the Agency finds that the levels of performance for one or more technologies are not statistically different, EPA averages the performance values achieved by each technology and then multiplies this value by the largest variability factor associated with any of the technologies.

(3) Quality assurance/quality control. This section presents the principal quality assurance/quality control (QA/QC) procedures employed in screening and adjusting the data to be used in the calculation of treatment standards. Additional QA/QC procedures used in collecting and screening data for the BDAT program are presented in EPA's Generic Quality Assurance Project Plan for Land Disposal Restrictions Program ("BDAT"), EPA/530-SW-87-011.

To calculate the treatment standards for the land disposal restriction rules, it is first necessary to determine the recovery value for each constituent (the amount of constituent recovered after spiking--which is the addition of a known amount of the constituent--minus the initial concentration in the samples, all divided by the spike amount added) for each spiked sample of the treated residual. Once the recovery values are determined, the following procedures are used to select the appropriate percent recovery value to adjust the analytical data:

1. If duplicate spike recovery values are available for the constituent of interest, the data are adjusted by the lowest available percent recovery value (i.e., the value that will yield the most conservative estimate of treatment achieved). However, if a spike recovery value of less than 20 percent is reported for a specific constituent, the data are not used to set treatment standards because the Agency does not have sufficient confidence in the reported value to set a national standard.

2. If data are not available for a specific constituent but are available for an isomer, then the spike recovery data are transferred from the isomer and the data are adjusted using the percent recovery selected according to the procedure described in (1) above.

3. If data are not available for a specific constituent but are available for a similar class of constituents (e.g., volatile organics, acid-extractable semivolatiles), then spike recovery data available for this class of constituents are transferred. All spike recovery values greater than or equal to 20 percent for a spike sample are averaged and the constituent concentration is adjusted by the average recovery value. If spiked recovery data are available for more than one sample, the average is calculated for each sample and the data are adjusted by using the lowest average value.

4. If matrix spike recovery data are not available for a set of data to be used to calculate treatment standards, then matrix spike recovery data are transferred from a waste that the Agency believes is similar (e.g., if the data represent an ash from incineration, then data from other incinerator ashes could be used). While EPA recognizes that transfer of matrix spike recovery data from a similar waste is not an exact analysis, this is considered the best approach for adjusting the data to account for the fact that most analyses do not result in extraction of 100 percent of the constituent. In assessing the recovery data to be transferred, the procedures outlined in (1), (2), and (3) above are followed.

The analytical procedures employed to generate the data used to calculate the treatment standards are listed in Appendix B of this document. In cases where alternatives or equivalent procedures and/or equipment are allowed in EPA's SW-846, Third Edition methods, the specific procedures and equipment used are documented. In addition, any deviations from the SW-846, Third Edition methods used to analyze the specific waste matrices are documented. It is important to note that the Agency will use the methods and procedures delineated in Appendix B to enforce the treatment standards presented in Section 7 of this document. Accordingly, facilities should use these procedures in assessing the performance of their treatment systems.

1.2.7 BDAT Treatment Standards for "Derived-From" and "Mixed" Wastes

(1) Wastes from treatment trains generating multiple residues. In a number of instances, the proposed BDAT consists of a series of operations, each of which generates a waste residue. For example, the proposed BDAT for a certain waste code is based on solvent extraction, steam stripping, and activated carbon adsorption. Each of these treatment steps generates a waste requiring treatment--a solvent-containing stream from solvent extraction, a stripper overhead, and spent activated carbon. Treatment of these wastes may generate further residues; for instance, spent activated carbon (if not regenerated) could be incinerated, generating an ash and possibly a scrubber water waste. Ultimately, additional wastes are generated that may require land disposal. With respect to these wastes, the Agency wishes to emphasize the following points:

1. All of the residues from treating the original listed wastes are likewise considered to be the listed waste by virtue of the derived-from rule contained in 40 CFR 261.3(c)(2). (This point is discussed more fully in (2) below.) Consequently, all of the wastes generated in the course of treatment would be prohibited from land disposal unless they satisfy the treatment standard or meet one of the exceptions to the prohibition.

2. The Agency's proposed treatment standards generally contain a concentration level for wastewaters and a concentration level for nonwastewaters. The treatment standards apply to all of the wastes generated in treating the original prohibited waste. Thus, all derived-from wastes meeting the Agency definition of wastewater (less than 1 percent total organic carbon (TOC) and less than 1 percent total suspended solids) would have to meet the treatment standard for wastewaters. All residuals not meeting this definition would have to meet the treatment standard for nonwastewaters. EPA wishes to make clear that this approach is not meant to allow partial treatment in order to comply with the applicable standard.

3. The Agency has not performed tests, in all cases, on every waste that can result from every part of the treatment train. However, the Agency's treatment standards are based on treatment of the most concentrated form of the waste. Consequently, the Agency believes that the less concentrated wastes generated in the course of treatment will also be able to be treated to meet this value.

(2) Mixtures and other derived-from residues. There is a further question as to the applicability of the BDAT treatment standards to residues generated not from treating the waste (as discussed above), but from other types of management. Examples are contaminated soil or leachate that is derived from managing the waste. In these cases, the mixture is still deemed to be the listed waste, either because of the derived-from rule (40 CFR 261.3(c)(2)(i)) or the mixture rule (40 CFR 261.3(a)(2)(iii) and (iv)) or because the listed waste is contained in the matrix (see, for example, 40 CFR 261.33(d)). The prohibition for the particular listed waste consequently applies to this type of waste.

The Agency believes that the majority of these types of residues can meet the treatment standards for the underlying listed wastes (with the possible exception of contaminated soil and debris for which the Agency is currently investigating whether it is appropriate to establish a separate treatability subcategorization). For the most part, these residues will be less concentrated than the original listed waste. The Agency's treatment standards also make a generous allowance for process variability by assuming that all treatability values used to establish the standard are lognormally distributed. The waste also might be amenable to a relatively nonvariable form of treatment technology such as incineration. Finally, and perhaps most important, the rules contain a treatability variance that allows a petitioner to demonstrate that its waste cannot be treated to the level specified in the rule (40 CFR Part 268.44(a)). This provision provides a safety valve that allows persons with unusual waste matrices to demonstrate the aporopriateness of a different standard. The Agency, to date, has not received any petitions under this provision (for example, for residues contaminated with a prohibited solvent waste), indicating, in the Agency's view, that the existing standards are generally achievable.

(3) Residues from managing listed wastes or that contain listed wastes. The Agency has been asked if and when residues from managing hazardous wastes, such as leachate and contaminated ground water, become subject to the land disposal prohibitions. Although the Agency believes this question to be settled by existing rules and interpretative statements, to avoid any possible confusion the Agency will address the question again.

Residues from managing First Third wastes, listed California List wastes, and spent solvent and dioxin wastes are all considered to be subject to the prohibitions for the listed hazardous waste as originally generated. Residues from managing California List wastes likewise are subject to the California List prohibitions when the residues themselves exhibit a characteristic of hazardous waste. This determination stems directly from the derived-from rule in 40 CFR 261.3(c)(2) or, in some cases, from the fact that the waste is mixed with or otherwise contains the listed waste. The underlying principle stated in all of these provisions is that listed wastes remain listed until delisted.

The Agency's historic practice in processing delisting petitions that address mixing residuals has been to consider them to be the listed waste and to require that delisting petitioners address all constituents for which the derived-from waste (or other mixed waste) was listed. The language in 40 CFR 260.22(b) states that mixtures or derived-from residues can be delisted provided a delisting petitioner makes a demonstration identical to that which a delisting petitioner would make for the original listed waste. Consequently, these residues are treated as the original listed waste for delisting purposes. The statute likewise takes this position, indicating that soil and debris that are contaminated with listed spent solvents or dioxin wastes are subject to the prohibition for these wastes even though these wastes are not the originally generated waste, but rather are a residual from management (RCRA section 3004(e)(3)). It is EPA's view that all such residues are covered by the existing prohibitions and treatment standards for the listed hazardous waste that these residues contain or from which they are derived.

1.2.8 Transfer of Treatment Standards

EPA is proposing some treatment standards that are not based on testing of the treatment technology on the specific waste subject to the treatment standard. The Agency has determined that the constituents present in the untested waste can be treated to the same performance levels as those observed in other wastes for which EPA has previously developed treatment data. EPA believes that transferring treatment performance data for use in establishing treatment standards for untested wastes is technically valid in cases where the untested wastes are generated from similar industries or processing steps, or have similar waste characteristics affecting performance and treatment selection. Transfer of treatment standards to similar wastes or wastes from similar processing steps requires little formal analysis. However, in a case where only the industry is similar, EPA more closely examines the waste characteristics prior to deciding whether the untested waste constituents can be treated to levels associated with tested wastes.

EPA undertakes a two-step analysis when determining whether constituents in the untested wastes can be treated to the same level of performance as in the tested waste. First, EPA reviews the available waste characterization data to identify those parameters that are expected to affect treatment selection. EPA has identified some of the most important constituents and other parameters needed to select the treatment technology appropriate for the given waste(s) in Section 3.

Second, when analysis suggests that an untested waste can be treated with the same technology as a waste for which treatment performance data are already available, EPA analyzes a more detailed list of characteristics that the Agency believes will affect the performance of the technology. By examining and comparing these characteristics, the Agency determines whether the untested wastes will achieve the same level of treatment as the tested waste. Where the Agency determines that the untested waste can be treated as well or better than the tested waste, the treatment standards can be transferred.

1.3 Variance from the BDAT Treatment Standard

The Agency recognizes that there may exist unique wastes that cannot be treated to the level specified as the treatment standard. In such a case, a generator or owner/operator may submit a petition to the Administrator requesting a variance from the treatment standard. A particular waste may be significantly different from the wastes on which the treatment standards are based because the subject waste contains a more complex matrix that makes it more difficult to treat. For example, complex mixtures may be formed when a restricted waste is mixed with other waste streams by spills or other forms of inadvertent mixing. As a result, the treatability of the restricted waste may be altered such that it cannot meet the applicable treatment standard.

Variance petitions must demonstrate that the treatment standard established for a given waste cannot be met. This demonstration can be made by showing that attempts to treat the waste by available technologies were not successful or by performing appropriate analyses of the waste, including waste characteristics affecting performance, which demonstrate that the waste cannot be treated to the specified levels. Variances will not be granted based solely on a showing that adequate BDAT treatment capacity is unavailable. (Such demonstrations can be made according to the provisions in Part 268.5 of RCRA for case-by-case extensions of the effective date.) The Agency will consider granting generic petitions provided that representative data are submitted to support a variance for each facility covered by the petition.

Petitioners should submit at least one copy to:

The Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

An additional copy marked "Treatability Variance" should be submitted to:

Chief, Waste Treatment Branch
Office of Solid Waste (WH-565)
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

Petitions containing confidential information should be sent with only the inner envelope marked "Treatability Variance" and "Confidential Business Information" and with the contents marked in accordance with the requirements of 40 CFR Part 2 (41 FR 36902, September 1, 1976, amended by 43 FR 4000).

The petition should contain the following information:

1. The petitioner's name and address.
2. A statement of the petitioner's interest in the proposed action.
3. The name, address, and EPA identification number of the facility generating the waste, and the name and telephone number of the plant contact.
4. The process(es) and feed materials generating the waste and an assessment of whether such process(es) or feed materials may produce a waste that is not covered by the demonstration.
5. A description of the waste sufficient for comparison with the waste considered by the Agency in developing BDAT, and an estimate of the average and maximum monthly and annual quantities of waste covered by the demonstration. (Note: The petitioner should consult the appropriate BDAT background document for determining the characteristics of the wastes considered in developing treatment standards.)
6. If the waste has been treated, a description of the system used for treating the waste, including the process design and operating conditions. The petition should include the reasons the treatment standards are not achievable and/or why the petitioner believes the standards are based on inappropriate technology for treating the waste. (Note: The petitioner should refer to the BDAT background document as guidance for determining the design and operating parameters that the Agency used in developing treatment standards.)
7. A description of the alternative treatment systems examined by the petitioner (if any); a description of the treatment system deemed appropriate by the petitioner for the waste in question; and, as appropriate, the concentrations in the treatment residual or extract of the treatment residual (i.e., using the TCLP, where appropriate, for stabilized metals) that can be achieved by applying such treatment to the waste.
8. A description of those parameters affecting treatment selection and waste characteristics that affect performance, including results of all analyses. (See Section 3 for a discussion of

waste characteristics affecting performance that the Agency has identified for the technology representing BDAT.)

9. The dates of the sampling and testing.
10. A description of the methodologies and equipment used to obtain representative samples.
11. A description of the sample handling and preparation techniques, including techniques used for extraction, containerization, and preservation of the samples.
12. A description of analytical procedures used, including QA/QC methods.

After receiving a petition for a variance, the Administrator may request any additional information or waste samples that may be required to evaluate and process the petition. Additionally, all petitioners must certify that the information provided to the Agency is accurate under 40 CFR 268.4(b).

In determining whether a variance will be granted, the Agency will first look at the design and operation of the treatment system being used. If EPA determines that the technology and operation are consistent with BDAT, the Agency will evaluate the waste to determine if the waste matrix and/or physical parameters are such that the BDAT treatment standards reflect treatment of this waste. Essentially, this latter analysis will concern the parameters affecting treatment selection and waste characteristics affecting performance parameters.

In cases where BDAT is based on more than one technology, the petitioner will need to demonstrate that the treatment standard cannot be met using any of the technologies, or that none of the technologies are appropriate for treatment of the waste. After the Agency has made a determination on the petition, the Agency's findings will be published in the Federal Register, followed by a 30-day period for public comment. After review of the public comments, EPA will publish its final determination in the Federal Register as an amendment to the treatment standards in 40 CFR Part 268, Subpart D.

2. INDUSTRY AFFECTED AND WASTE CHARACTERIZATION

According to 40 CFR 261.32, the waste identified as K022 is listed as follows:

> K022 - Distillation bottom tars from the production of phenol/acetone from cumene.

This section discusses the industry affected by the land disposal restrictions for K022 waste, describes the process generating the waste, and presents a summary of available waste characterization data.

2.1 Industry Affected and Process Description

The Agency estimates that eight facilities in the United States produce phenol and acetone from cumene and thus generate K022 waste. The facilities are located in the eastern, central, and southern States. Table 2-1 lists these facilities and their locations.

The cumene process consists of the following basic steps: (1) oxidation of cumene to a concentrated cumene hydroperoxide; (2) cleavage of the cumene hydroperoxide to phenol and acetone along with a variety of other products (e.g., cumylphenols, acetophenone, dimethyl phenyl carbinol, and alpha methyl styrene); (3) neutralization of the cleaved products with sodium hydroxide or other suitable base or with ion-exchange resins; and (4) separation of the phenol and acetone using a series of distillation columns. A flow diagram for the cumene production process is presented in Figure 2-1.

Table 2-1 Facilities That Produce Phenol and Acetone from Cumene--by State and EPA Region

State	EPA Region	Facility name and location
Illinois	V	BTL Specialty Resins Corp. Blue Island, Illinois
Indiana	V	General Electric Company Plastics Business Operations Mount Vernon, Indiana
Kansas	VII	Texaco, Inc. Texaco Chemical Company, subsidiary El Dorado, Kansas
Louisiana	VI	Georgia Gulf Corporation Plaquemine, Louisiana
Ohio	V	Aristech Chemical Corporation Haverhill, Ohio
Pennsylvania	III	Allied Signal, Inc. Allied Corp., Chemical Sector Frankford, Pennsylvania
Texas	VI	Dow Chemical U.S.A. Oyster Creek, Texas
Texas	VI	Shell Oil Company Shell Chemical Company, division Deer Park, Texas

Reference: SRI 1987.

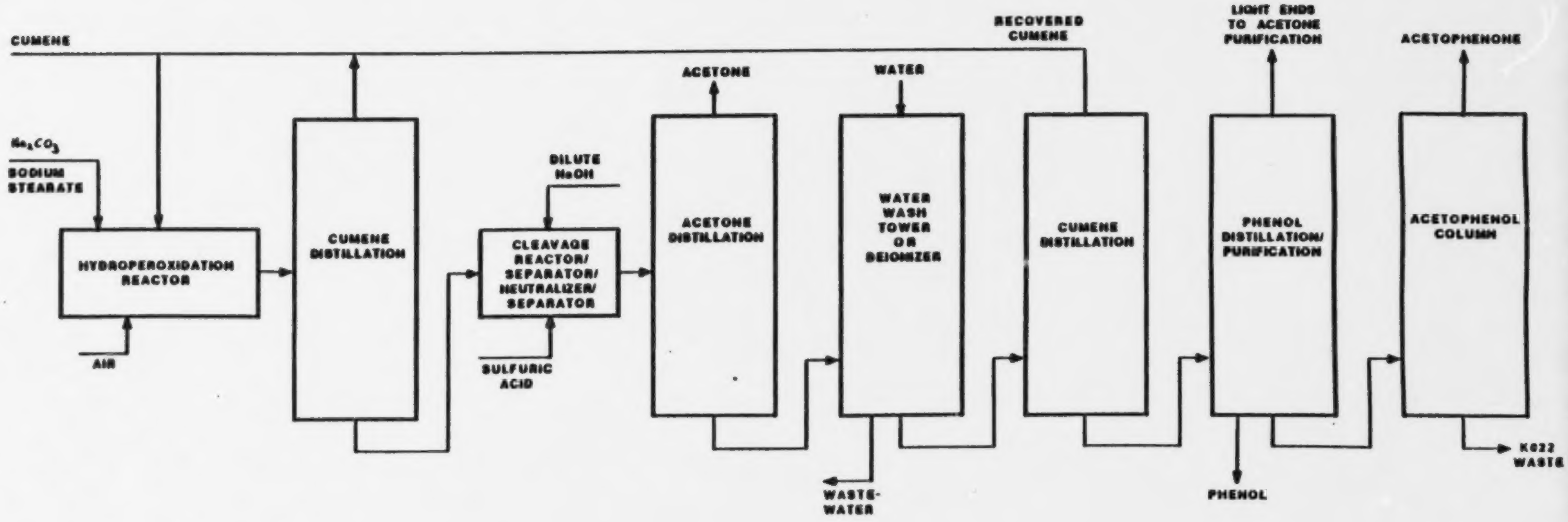

FIGURE 2-1 SCHEMATIC DIAGRAM FOR PRODUCTION OF PHENOL AND ACETONE FROM CUMENE

Cumene hydroperoxide is the first reaction product when cumene is oxidized with air at 130°C in an aqueous sodium carbonate medium. The reaction mix is circulated to a vacuum column where untreated cumene is separated from the mix. The cumene is recycled to the reactor and any alpha methyl styrene contained in the recovered cumene is separated by distillation. The recovered alpha methyl styrene can undergo further processing, be sold, or be incinerated. The cumene hydroperoxide mixture from the bottoms products of the vacuum column is reacted with 10 to 25 percent sulfuric acid at about 60°C and co-mixed with an inert solvent (such as benzene) to extract organic material from the aqueous acid. After settling, the acid phase is separated out and recycled to the process. The organic phase is neutralized with sodium hydroxide (or another suitable base) or with ion-exchange resins. The resultant aqueous waste stream, which contains sodium sulfate, sodium phenate, phenol, acetone, and sodium stearate, is separated and sent to wastewater treatment. The crude, neutralized organic layer is sent to a series of distillation columns where acetone, cumene, phenol, acetophenone, and the solvent are recovered. The first column separates a crude acetone product overhead that is further purified by distillation. The bottoms from the acetone distillation column are passed through a water scrubber to remove residual acetone and inorganic salts. The bottoms are then passed through a series of columns where the lower boiling hydrocarbons, solvents, cumene, and alpha methyl styrene are removed and subsequently recovered, recycled, or disposed of. The crude phenol is refined in the next distillation column. The purified phenol is removed overhead and the bottoms may be further distilled to recover acetophenone. The still bottoms remaining at the completion of distillation are the waste stream K022.

2.2 Waste Characterization

This section includes all waste characterization data available to the Agency for K022 waste. The approximate percent concentrations of the major constituents composing K022 waste are listed in Table 2-2. The percent concentration in the waste was determined from engineering judgment based on analytical results and literature data. The ranges of BDAT constituents present in the waste and all other available parameters affecting treatment selection data are presented in Table 2-3. The data show a waste with high concentrations of organic constituents (approximately 82 to 93 percent as indicated by total organic carbon levels), low concentrations of moisture, and low ash content. Individual BDAT constituent concentrations include approximately 0.1 to 50 percent acetophenone, 0.1 to 10 percent phenol, and less than 0.1 percent other BDAT list constituents.

Table 2-2 Constituent Analysis of Untreated K022 Waste

Constituent	Range of concentration data (wt %)
Acetophenone	0.1-50
Phenol	0.1-10
Other BDAT constituents	<0.1
Tars[a]	1-50
Total organic carbon[b]	82-93

[a] Tars may include acetophenone and phenol, as well as other polyaromatic ring structures.

[b] Total organic carbon includes the carbon from the acetophenone, phenol, tars, alpha methyl styrene, cumylphenol, etc.

Reference: Environ 1985.

Table 2-3 BDAT Constituent Concentrations and Other Data

BDAT ref. no.	BDAT list constituent	Untreated waste concentration (mg/kg) Plant 1	 Plant 2

This table contains RCRA Confidential Business Information.

3. APPLICABLE/DEMONSTRATED TREATMENT TECHNOLOGIES

This section describes the applicable and demonstrated treatment technologies for K022 waste. The identification of these treatment technologies is based on data obtained from field testing, data submitted by industry, and current literature sources. Detailed discussions are provided for the demonstrated technologies.

3.1 Applicable Treatment Technologies

The Agency has identified fuel substitution and incineration as being applicable for BDAT list organics in K022 waste. Fuel substitution and incineration technologies are designed to destroy the toxic organics present in the waste fuel. Use of these technologies results in a residual ash that may contain BDAT list metals, the applicable technology for which is stabilization. Stabilization is designed to reduce the leachability of metals in the treated residual. Note that both fuel substitution and incineration may result in a residual scrubber water that requires further treatment for metals. The applicable technologies for such a residual are chemical precipitation, chromium reduction, and other wastewater treatment technologies.

3.2 Demonstrated Treatment Technologies

The technologies demonstrated for the BDAT list organics in this waste or in wastes with similar parameters affecting treatment selection (i.e., high organic content, low water content, and low ash content) are fuel substitution and incineration, including liquid injection incineration, rotary kiln incineration, and fluidized bed incineration.

EPA believes fuel substitution is a demonstrated treatment technology for untreated K022 waste because fuel substitution is being used on a full-scale basis to treat this and similar waste. The Agency knows of six generators using fuel substitution for treatment of K022 waste specifically. Performance data collected by EPA for fuel substitution of K022 waste in an industrial boiler are discussed in Section 4. A discussion of fuel substitution is presented in Section 3.2.1.

EPA is not aware of any generators or TSD facilities currently using incineration for treatment of K022 waste. While performance data are not available for incineration, this technology has been demonstrated on wastes with similar waste characteristics affecting performance. A discussion of incineration treatment technologies is presented in Section 3.2.2.

EPA also is not aware of any generator or treatment, storage, and disposal (TSD) facility currently using stabilization for treatment of the residuals obtained from treatment of K022 wastes. However, stabilization has been demonstrated for BDAT list metals in kiln ash residues and other nonwastewater wastes, e.g., F006 waste. The parameters affecting treatment selection in such wastes are similar to those of K022 ash residues. Thus, the Agency believes that stabilization is, for the purposes of the BDAT program, demonstrated for K022 inorganic nonwastewaters. A discussion of stabilization is presented in Section 3.2.3.

EPA knows of at least one facility that generates K022 wastewater as a scrubber water. Other potential sources of K022 wastewater include CERCLA site wastes, RCRA facility corrective action wastes, and landfill leachates. The Agency is not aware of any generator or TSD facility that currently treats such wastewaters. Because characterization data are not available for K022 wastewater specifically, the Agency cannot identify similar wastes or technologies that are demonstrated for the similar wastes and therefore for K022 wastewaters.

The Agency intends to collect data on K022 wastewater, identify demonstrated technologies, and develop BDAT treatment standards by May 8, 1990.

3.2.1 Fuel Substitution

Fuel substitution involves using hazardous waste as a fuel in industrial furnaces or in boilers for generation of steam. The hazardous waste may be blended with other nonhazardous wastes (e.g., municipal sludge) and/or fossil fuels.

(1) Applicability and use of fuel substitution. Fuel substitution has been used with industrial waste solvents, refinery wastes, synthetic fibers/petrochemical wastes, and waste oils. It can also be used when combusting other waste types produced during the manufacturing of pharmaceuticals, pulp and paper, and pesticides. These wastes can be handled in a solid, liquid, or gaseous form.

The most common types of units in which waste fuels are burned are industrial furnaces and industrial boilers. Industrial furnaces include a diverse variety of industrial processes that produce heat and/or products by burning fuels. They include blast furnaces, smelters, and coke ovens. Industrial boilers are units wherein fuel is used to produce steam for process and plant use. Industrial boilers typically use coal, oil, or gas as the primary fuel source.

A number of parameters affect the selection of fuel substitution. These parameters are:

- Halogen content of the waste;
- Inorganic solids content (ash content) of the waste, particularly heavy metals;
- Heating value of the waste;
- Viscosity of the waste (for liquids);
- Filterable solids concentration (for liquids); and
- Sulfur content.

If halogenated organics are burned, halogenated acids and free halogen are among the products of combustion. These released corrosive gases may require subsequent treatment prior to venting to the atmosphere. Also, halogens and halogenated acids formed during combustion are likely to severely corrode boiler tubes and other process equipment. To minimize such problems, halogenated wastes are blended into fuels only at very low concentrations. High chlorine content can also lead to the incidental production (at very low concentrations) of other hazardous compounds such as polychlorinated biphenyls (PCBs), chlorinated dibenzo-p-dioxins (PCDDs), chlorinated dibenzofurans (PCDFs), and chlorinated phenols.

High inorganic solids content (i.e., ash content) of wastes may cause two problems: (1) scaling in the boiler and (2) particulate air emissions. Scaling results from deposition of inorganic solids on the walls of the boiler. Particulate emissions are produced by noncombustible inorganic constituents that flow out of the boiler with the gaseous combustion products. Because of these problems, wastes with significant concentrations of inorganic materials are usually not handled in boilers unless they have an air pollution control system.

Industrial furnaces vary in their tolerance to inorganic constituents. Heavy metal concentrations, found in both halogenated and nonhalogenated wastes used as fuel, can cause environmental concern because they may be emitted in the gaseous emissions from the combustion process, in the ash residues, or in any produced solids. The partitioning of the heavy metals to these residual streams primarily depends on the volatility of the metal, the waste matrix, and the furnace design.

The heating value of the waste must be sufficiently high (either alone or in combination with other fuels) to maintain combustion temperatures consistent with efficient waste destruction and operation of the boiler or furnace. For many applications, only supplemental fuels having minimum heating values of 4,400 to 5,600 kcal/kg (8,000 to 10,000 Btu/lb) are considered to be feasible. Below this value, the unblended fuel would not be likely to maintain a stable flame, and its combustion would release insufficient energy to provide the needed steam generation potential in the boiler or the necessary heat for an industrial furnace. Some wastes with heating values of less than 4,400 kcal/kg (8,000 Btu/lb) can be used if sufficient auxiliary fuel is employed to support combustion or if special designs are incorporated into the combustion device. Occasionally, for wastes with heating values higher than virgin fuels, blending with auxiliary fuel may be required to prevent overheating or overcharging the combustion device.

In combustion devices designed to burn liquid fuels, the viscosity of the liquid waste must be low enough that it can be atomized in the combustion chamber. If viscosity is too high, heating of storage tanks may be required prior to combustion. For atomization of liquids, a viscosity of 165 centistokes (750 Saybolt Seconds Universal (SSU)) or less is typically required.

If filterable material suspended in the liquid fuel prevents or hinders pumping or atomization, it will be unacceptable.

Sulfur content in the waste may prevent burning of the waste because of the potential for atmospheric emissions of sulfur oxides. For instance, Federal sulfur oxide emission regulations have been proposed for certain new source industrial boilers (51 FR 22385). Air pollution control devices are available to remove sulfur oxides from the stack gases.

(2) Underlying principles of operation. For a boiler and most industrial furnaces there are two distinct principles of operation. Initially, energy in the form of heat is transferred to the waste to

achieve volatilization of the various waste constituents. For liquids, volatilization energy may also be supplied by using pressurized atomization. The energy used to pressurize the liquid waste allows the atomized waste to break into smaller particles, thus enhancing its rate of volatilization. The volatilized constituents then require additional energy to destabilize the chemical bonds and allow the constituents to react with oxygen to form carbon dioxide and water vapor. The energy needed to destabilize the chemical bonds is referred to as the energy of activation.

(3) Description of the fuel substitution process. As stated previously, a number of industrial applications can use fuel substitution; therefore, no one process description will fit all of these applications. However, the following section provides a general description of industrial kilns (one form of industrial furnace) and industrial boilers.

(a) Kilns. Combustible wastes have the potential to be used as fuel in kilns and, for waste liquids, are often used with oil to co-fire kilns. Coal-fired kilns are capable of handling some solid wastes. In the case of cement kilns, there are usually no residuals requiring land disposal, since any ash formed becomes part of the product or is removed by particulate collection systems and recycled back to the kiln. The only residuals may be low levels of unburned gases that escape with the combustion products. If this is the case, air pollution control devices may be required.

Three types of kilns are particularly applicable: cement kilns, lime kilns, and lightweight aggregate kilns.

(i) Cement kilns. The cement kiln is a rotary furnace that is a refractory-lined steel shell used to calcine a mixture of calcium, silicon, aluminum, iron, and magnesium-containing minerals. The kiln is normally fired by coal or oil. Liquid and solid combustible wastes may then serve as auxiliary fuel. Temperatures within the kiln are typically between 1,380 and 1,540°C (2,500 to 2,800°F). To date, only liquid hazardous wastes have been burned in cement kilns.

Most cement kilns have a dry particulate collection device (i.e., either an electrostatic precipitator or a baghouse) with the collected fly ash recycled back to the kiln. Buildup of metals or other noncombustibles is prevented through their incorporation in the product cement. Many types of cement require a source of chloride so that most halogenated liquid hazardous wastes currently can be burned in cement kilns. Available information shows that scrubbers are not used.

(ii) Lime kilns. Quick-lime (CaO) is manufactured in a calcination process using limestone ($CaCO_3$) or dolomite ($CaCO_3$ and $MgCO_3$). These raw materials are also heated in a refractory-lined rotary kiln, typically to temperatures of 980 to 1,260°C (1,800 to 2,300°F). Lime kilns are less likely to burn hazardous wastes than are cement kilns because product lime is often added to potable water systems. Only one lime kiln currently burns hazardous waste in the U.S. That particular facility sells its product lime for use as flux or as refractory in blast furnaces.

As with cement kilns, any collected fly ash is recycled back to the lime kiln, resulting in no residual streams from the kiln. Available information shows that scrubbers are not used.

(iii) Lightweight aggregate kilns. Lightweight aggregate kilns heat clay to produce an expanded lightweight inorganic material used in portland cement formulations and other applications. The kiln has a normal temperature range of 1,100 to 1,150°C (2,000 to 2,100°F). Lightweight aggregate kilns are less amenable to combustion of hazardous wastes as fuels than are the other kilns described above because these kilns lack material to adsorb halogens. As a result, burning of halogenated organics in such kilns would likely require afterburners to ensure complete destruction of the halogenated organics and scrubbers to control acid gas production. Such controls would produce a wastewater residual stream subject to treatment standards.

(b) Industrial boilers. A boiler is a closed vessel in which water is transformed into steam by the application of heat. Normally, heat is supplied by the combustion of pulverized coal, fuel oil, or gas. These fuels are fired into a combustion chamber with nozzles and burners that provide mixing with air. Liquid wastes, and granulated solid wastes in the case of grate-fired boilers, can be burned as auxiliary fuel in a boiler. Few grate-fired boilers burn hazardous wastes, however. For liquid-fired boilers, residuals requiring land disposal are only generated when the boiler is shut down and cleaned. This is generally done once or twice per year. Other residuals from liquid-fired boilers would be the gas emission stream, which would consist of any products of incomplete combustion, along with the normal combustion products. For example, chlorinated wastes would produce acid gases. If this is the case, air pollution control devices may be required. For solid-fired boilers, an ash normally is generated. This ash may contain residual amounts of organics from the blended waste/fuels as well as noncombustible materials. Land disposal of this ash would require compliance with applicable BDAT treatment standards.

(4) Waste characteristics affecting performance. For cement kilns, lime kilns, and lightweight aggregate kilns burning nonhalogenated wastes (i.e., no scrubber is needed to control acid gases), no residual waste streams would be produced. Any noncombustible material in the waste would leave the kiln in the product stream. As a result, in transferring standards EPA would not examine waste characteristics affecting performance, but rather would determine the applicability of fuel substitution. That is, EPA would investigate the parameters affecting treatment selection. For kilns these parameters (as mentioned previously) are Btu content, percent filterable solids, halogenated organics content, viscosity, and sulfur content.

Lightweight aggregate kilns burning halogenated organics and boilers burning wastes containing any noncombustibles will produce residual streams subject to treatment standards. In determining whether fuel substitution is likely to achieve the same level of performance on an untreated waste as on a previously treated waste, EPA will examine: (1) relative volatility of the waste constituents, (2) the heat transfer characteristics (for solids), and (3) the activation energy for combustion.

(a) Relative volatility. The term relative volatility (α) refers to the ease with which a substance present in a solid or a liquid waste will vaporize from that waste upon application of heat from an external source. Hence, it bears a relationship to the equilibrium vapor pressure of the substance.

EPA recognizes that the relative volatilities cannot be measured or calculated directly for the types of wastes generally treated in an industrial boiler or furnace. The Agency believes that the best measure of relative volatility is the boiling point of the various hazardous constituents, and therefore will use this parameter in assessing volatility of the organic constituents.

(b) Heat transfer characteristics. Consistent with the underlying principles of combustion in aggregate kilns or boilers, a major factor with regard to whether a particular constituent will volatilize is the transfer of heat through the waste. In the case of industrial boilers burning solid fuels, heat is transferred through the waste by three mechanisms: radiation, convection, and conduction. For a given boiler it can be assumed that the type of waste will have a minimal impact on the heat transferred from radiation. With regard to convection, EPA believes that the range of wastes treated would exhibit similar properties with regard to the amount of heat transferred by convection. Therefore, EPA will not evaluate radiation convection heat transfer properties of wastes in determining similar treatability. For solids, the third heat transfer mechanism, conductivity, is the one principally operative or most likely to change between wastes.

Using thermal conductivity measurements as part of a treatability comparison for two different wastes through a given boiler or furnace is most meaningful when applied to wastes that are homogeneous. As wastes exhibit greater degrees of nonhomogeneity, thermal conductivity becomes less accurate in predicting treatability, because the measurement essentially reflects heat flow through regions having the greatest conductivity (i.e., the path of least resistance and not heat flow through all parts of the waste). Nevertheless, EPA has not identified a better alternative to thermal conductivity, even for wastes that are nonhomogeneous.

Other parameters considered for predicting heat transfer characteristics were Btu value, specific heat, and ash content. These parameters can neither better account for nonhomogeneity nor better predict heat transferability through the waste.

(c) Activation energy. Given an excess of oxygen, an organic waste in an industrial furnace or boiler would be expected to convert to carbon monoxide and water provided that the activation energy is achieved. Activation energy is the quantity of heat (energy) needed to destabilize molecular bonds and create reactive intermediates so that the oxidation (combustion) reaction will proceed to completion. As a measure of activation energy, EPA is using bond dissociation energies. In theory, the bond dissociation energy would be equal to the activation energy; in practice, however, this is not always the case.

In some instances, bond energies will not be available and will have to be estimated, or other energy effects (e.g., vibrational) and other reactions will have a significant influence on activation energy. Because of the shortcomings of bond energies in estimating activation energy, therefore, EPA analyzed other waste characteristic parameters to determine if these parameters would provide a better basis for transferring treatment standards from an untested waste to a tested waste. These parameters included heat of combustion, heat of formation, use of available kinetic data to predict activation energies, and general structural class. All of these parameters were rejected for the reasons provided below.

The heat of combustion measures only the difference in energy of the products and reactants; it does not provide information on the transition state (i.e., the energy input needed to initiate the reaction). Heat of formation is used as a predictive tool to determine whether reactions are likely to proceed; however, data are not available for a significant number of hazardous constituents. Use of available kinetic data was rejected because while these data could be used to calculate some free energy values (ΔG), they could not be used for the wide range of hazardous constituents. Finally, EPA decided not to use structural classes because the Agency believes that evaluation of bond dissociation energies allows for a more direct comparison.

(5) Design and operating parameters.

(a) Design parameters. Cement kilns and lime kilns, along with aggregate kilns burning nonhalogenated wastes, produce no residual streams. Their design and operation is such that any wastes that are incompletely destroyed will be contained in the product. As a result, the Agency will not look at design and operating values for such devices, since treatment, per se, cannot be measured through detection of constituents in residual streams. In this instance, it is important merely to ensure that the waste is appropriate for combustion in the kilns and that the kiln is operated in a manner that will produce a usable product.

Specifically, cement, lime, and aggregate kilns are only demonstrated for liquid hazardous wastes. Such wastes must be sufficiently free of filterable solids to avoid plugging the burners at the hot end of the kiln. Viscosity also must be low enough to inject the waste into the kiln through the burners. The sulfur content is not a concern unless the concentration in the waste is sufficiently high as to exceed Federal, State, or local air pollution standards promulgated for industrial boilers.

The design parameters that normally affect the operation of an industrial boiler (and aggregate kilns with residual streams) with respect to hazardous waste treatment are (1) the design temperature, (2) the design retention time of the waste in the combustion chamber, and

(3) turbulence in the combustion chamber. Evaluation of these parameters would be important in determining if an industrial boiler or industrial furnace is adequately designed for effective treatment of hazardous wastes. The rationale for selection of these three parameters is given below.

(i) Design temperature. Industrial boilers are generally designed based on their steam generation potential (Btu output). This factor is related to the design combustion temperature, which in turn depends on the amount of fuel burned and its Btu value. The fuel feed rates and combustion temperatures of industrial boilers are generally fixed based on the Btu values of fuels normally handled (e.g., No. 2 versus No. 6 fuel oils). When wastes are to be blended with fossil fuels for combustion, the blending, based on Btu values, must be such that the resulting Btu value of the mixture is close to that of the fuel value used in the design of the boiler. Industrial furnaces also are designed to operate at specific ranges of temperature in order to produce the desired product (e.g., lightweight aggregate). The blended waste/fuel mixture should be capable of maintaining the design temperature range.

(ii) Retention time. A sufficient retention time of combustion products is normally necessary to ensure that the hazardous substances being combusted (or formed during combustion) are completely oxidized. Retention times on the order of a few seconds are generally needed at normal operating conditions. For industrial furnaces as well as boilers, the retention time is a function of the size of the furnace and the fuel feed rates. For most boilers and furnaces the retention time usually exceeds a few seconds.

(iii) Turbulence. Boilers are designed so that fuel and air are intimately mixed. This helps ensure that complete combustion takes place. The shape of the boiler and the method of fuel and air feed influence the turbulence required for good mixing. Industrial furnaces also are designed for turbulent mixing where fuel and air are mixed.

(b) Operating parameters. The operating parameters that normally affect the performance of an industrial boiler and many industrial furnaces with respect to treatment of hazardous wastes are (1) air feed rate, (2) fuel feed rate, (3) steam pressure or rate of production, and (4) temperature. EPA believes that these four parameters will be used to determine whether an industrial boiler burning blended fuels that contain hazardous waste constituents is operated properly. The rationale for selecting these four parameters is given below. Most industrial furnaces will monitor similar parameters, but some exceptions are noted.

(i) Air feed rate. An important operating parameter in boilers and many industrial furnaces is the oxygen content in the flue gas, which is a function of the air feed rate. Stable combustion of a fuel generally occurs within a specific range of air-to-fuel ratios. An oxygen analyzer in the combustion gases can be used to control the feed ratio of air to fuel to assure complete thermal destruction of the waste and efficient operation of the boiler. When necessary, the air feed rate can be increased or decreased to maintain proper fuel-to-oxygen ratios. Some industrial furnaces do not completely combust fuels (e.g., coke ovens and blast furnaces); hence, oxygen concentration in the flue gas is a meaningless variable.

(ii) Fuel feed rate. The rate at which fuel is injected into the boiler or industrial furnace will determine the thermal output of the system per unit of time (Btu/hr). If steam is produced, steam pressure monitoring will indirectly determine if the fuel feed rate is adequate. However, various velocity and mass measurement devices can be used to monitor fuel flow directly.

(iii) Steam pressure or rate of production. Steam pressure in boilers provides a direct measure of the thermal output of the system and is directly monitored by use of in-system pressure gauges. Increases or decreases in steam pressure can be effected by increasing or decreasing the fuel and air feed rates within certain operating design limits. Most industrial furnaces do not produce steam; instead, they produce a product (e.g., cement, aggregate) and monitor the rate of production.

(iv) Temperature. Temperatures are monitored and controlled in industrial boilers to assure the quality and flow rate of steam. Therefore, complex monitoring systems are frequently installed in the combustion unit to provide a direct reading of temperature. The efficiency of combustion in industrial boilers is dependent on combustion temperatures. Temperature may be adjusted to design settings by increasing or decreasing the air and fuel feed rates.

Wastes should not be added to primary fuels until the boiler temperature reaches the minimum needed for destruction of the wastes. Temperature instrumentation and control should be designed to stop the addition of waste in the event of process upsets.

Monitoring and control of temperature in industrial furnaces are also critical to the product quality, e.g., lime, cement, or aggregate kilns that require minimum operating temperatures. Kilns have very high thermal inertia in the refractory and in-process product, high residence times, and high air feed rates, so that even if the fuel flow to the kiln should stop momentarily, organic constituents would still continue to be destroyed. The main operational control required for wastes burned in kilns is to stop waste flow in the event of low kiln temperature, loss of electrical power to the combustion air fan, and loss of primary fuel flow.

(v) Other operating parameters. In addition to the four operating parameters discussed above, EPA considered and then discarded one additional parameter--fuel-to-waste blending ratios. However, while blending is done to yield a uniform Btu content fuel, blending ratios will vary greatly depending on the Btu content of the wastes and the fuels being used.

3.2.2 Incineration

This section addresses the commonly used incineration technologies: liquid injection, rotary kiln, fluidized bed, and fixed hearth. A discussion is provided regarding the applicability of these technologies, their underlying principles of operation, a technology description, waste characteristics that affect performance, and, finally, important design and operating parameters. As appropriate, the subsections are divided by type of incineration unit.

(1) Applicability and use of incineration.

(a) Liquid injection. Liquid injection is applicable to wastes that have viscosity values low enough that the waste can be atomized in the combustion chamber. A range of literature maximum viscosities are reported, with the low being 100 SSU and the high being 10,000 SSU. It is important to note that viscosity is temperature dependent so that while liquid injection may not be applicable to a waste at ambient conditions, it may be applicable when the waste is heated. Other factors that affect the use of liquid injection are particle size and the presence of suspended solids. Both of these waste parameters can cause plugging of the burner nozzle.

(b) Rotary kiln/fluidized bed/fixed hearth. These incineration technologies are applicable to a wide range of hazardous wastes. They can be used on wastes that contain high or low total organic content, high or low filterable solids, various viscosity ranges, and a number of other waste parameters. EPA has not found these technologies to be demonstrated on wastes that are composed essentially of metals with low organic concentrations. In addition, the Agency expects that some of the high metal content wastes may not be compatible with existing and future air emission limits without emission controls far more extensive than those currently practiced.

(2) Underlying principles of operation.

(a) Liquid injection. The basic operating principle of this incineration technology is that incoming liquid wastes are first volatilized and then additional heat is supplied to the waste to destabilize the chemical bonds. Once the chemical bonds are broken, these constituents react with oxygen to form carbon dioxide and water vapor. The energy needed to destabilize the bonds is referred to as the energy of activation.

(b) Rotary kiln and fixed hearth. There are two distinct principles of operation for these incineration technologies, one for each of the chambers involved. In the primary chamber, energy, in the form of heat, is transferred to the waste to achieve volatilization of the various organic waste constituents. During this volatilization process some of the organic constituents will oxidize to carbon dioxide and water vapor. In the secondary chamber, additional heat is supplied to overcome the energy requirements needed to destabilize the chemical bonds and allow the constituents to react with excess oxygen to form carbon dioxide and water vapor. The principle of operation for the secondary chamber is similar to that of liquid injection.

(c) Fluidized bed. The principle of operation for this incineration technology differs somewhat from that for rotary kiln and fixed hearth incineration relative to the functions of the primary and secondary chambers. In fluidized bed incineration, the purpose of the primary chamber is not only to volatilize the wastes but also to essentially combust the waste. Destruction of the waste organics can be better accomplished in the primary chamber of this technology than in rotary kiln and fixed hearth incineration because of (1) improved heat transfer from fluidization of the waste using forced air and (2) the fact that the fluidization process provides sufficient oxygen and turbulence to convert the organics to carbon dioxide and water vapor. The secondary chamber (referred to as the freeboard) generally does not have an afterburner; however, additional time is provided for conversion of the organic constituents to carbon dioxide, water vapor, and hydrochloric acid if chlorine is present in the waste.

(3) Description of the incineration process.

(a) Liquid injection. The liquid injection system is capable of incinerating a wide range of gases and liquids. The combustion system has a simple design with virtually no moving parts. A burner or nozzle atomizes the liquid waste and injects it into the combustion chamber where it burns in the presence of air or oxygen. A forced draft system supplies the combustion chamber with air to provide oxygen for combustion and turbulence for mixing. The combustion chamber is usually a cylinder lined with refractory (i.e., heat resistant) brick and can be fired horizontally, vertically upward, or vertically downward. Figure 3-1 illustrates a liquid injection incineration system.

(b) Rotary kiln. A rotary kiln is a slowly rotating, refractory-lined cylinder that is mounted at a slight incline from the horizontal (see Figure 3-2). Solid wastes enter at the high end of the kiln, and liquid or gaseous wastes enter through atomizing nozzles in the kiln or afterburner section. Rotation of the kiln exposes the solids to the heat, vaporizes them, and allows them to combust by mixing with air. The rotation also causes the ash to move to the lower end of the kiln where it can be removed. Rotary kiln systems usually have a secondary combustion chamber or afterburner following the kiln for further combustion of the volatilized components of solid wastes.

(c) Fluidized bed. A fluidized bed incinerator consists of a column containing inert particles such as sand, which is referred to as the bed. Air, driven by a blower, enters the bottom of the bed to fluidize the sand. Air passage through the bed promotes rapid and uniform mixing of the injected waste material within the fluidized bed. The fluidized bed has an extremely high heat capacity (approximately three times that of flue gas at the same temperature), thereby providing a large heat reservoir. The injected waste reaches the ignition

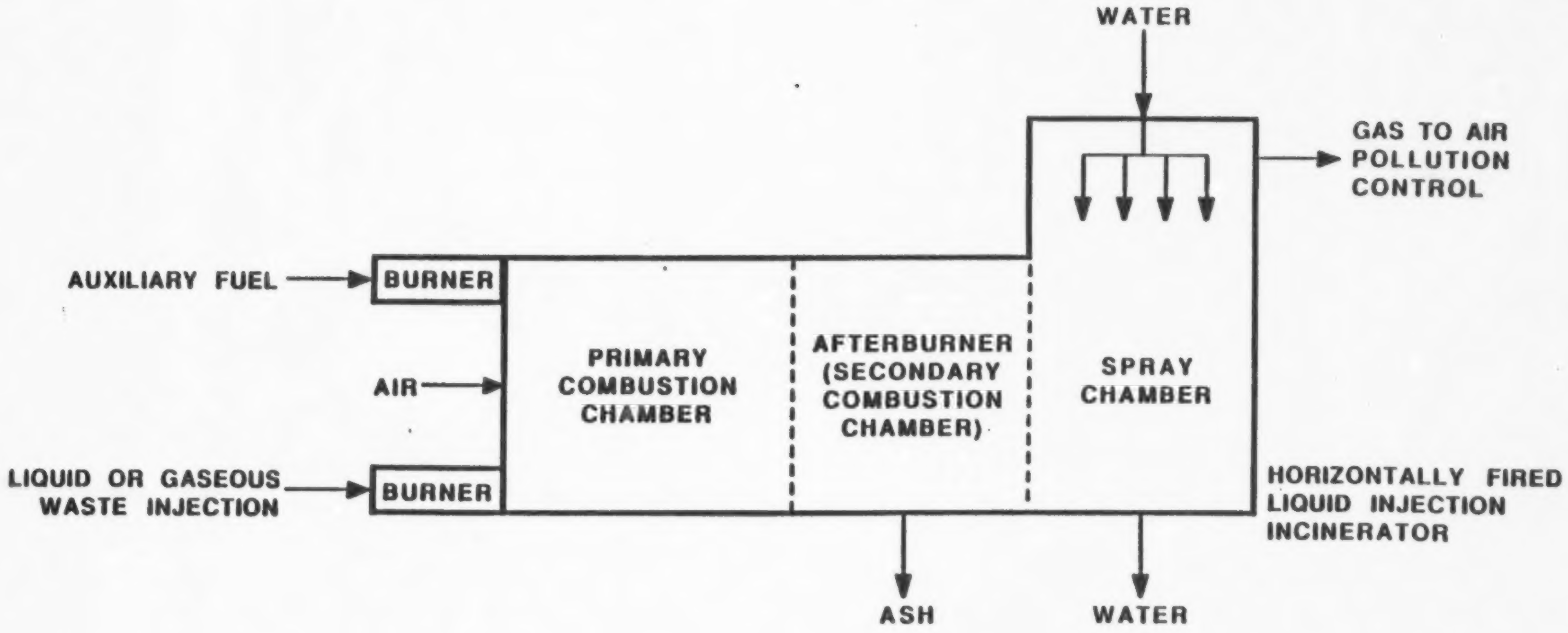
WATER
GAS TO AIR POLLUTION CONTROL
AUXILIARY FUEL
BURNER
AIR
LIQUID OR GASEOUS WASTE INJECTION
BURNER
PRIMARY COMBUSTION CHAMBER
AFTERBURNER (SECONDARY COMBUSTION CHAMBER)
SPRAY CHAMBER
HORIZONTALLY FIRED LIQUID INJECTION INCINERATOR
ASH
WATER

FIGURE 3-1
LIQUID INJECTION INCINERATOR

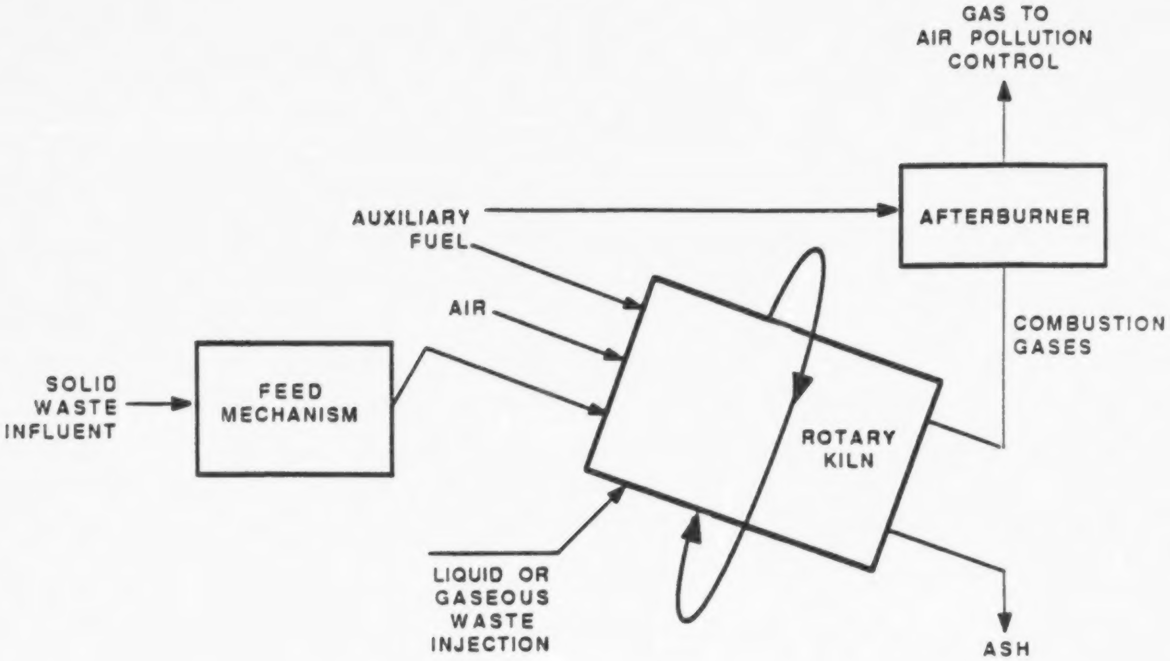

FIGURE 3-2
ROTARY KILN INCINERATOR

temperature quickly and transfers the heat of combustion back to the bed. Continued bed agitation by the fluidizing air allows larger particles to remain suspended in the combustion zone (see Figure 3-3).

(d) Fixed hearth incineration. Fixed hearth incinerators, also called controlled air or starved air incinerators, are another major technology used for hazardous waste incineration. Fixed hearth incineration is a two-stage combustion process (see Figure 3-4). Waste is ram-fed into the first stage, or primary chamber, and burned at less than stoichiometric conditions. The resultant smoke and pyrolysis products, consisting primarily of volatile hydrocarbons and carbon monoxide, along with the normal products of combustion, pass to the secondary chamber. Here, additional air is injected to complete the combustion. This two-stage process generally yields low stack particulate and carbon monoxide (CO) emissions. The primary chamber combustion reactions and combustion gas are maintained at low levels by the starved air conditions so that particulate entrainment and carryover are minimized.

(e) Air pollution controls. Following incineration of hazardous wastes, combustion gases are generally further treated in an air pollution control system. The presence of chlorine or other halogens in the waste requires a scrubbing or absorption step to remove hydrogen chloride and other halo-acids from the combustion gases. Ash in the waste is not destroyed in the combustion process. Depending on its

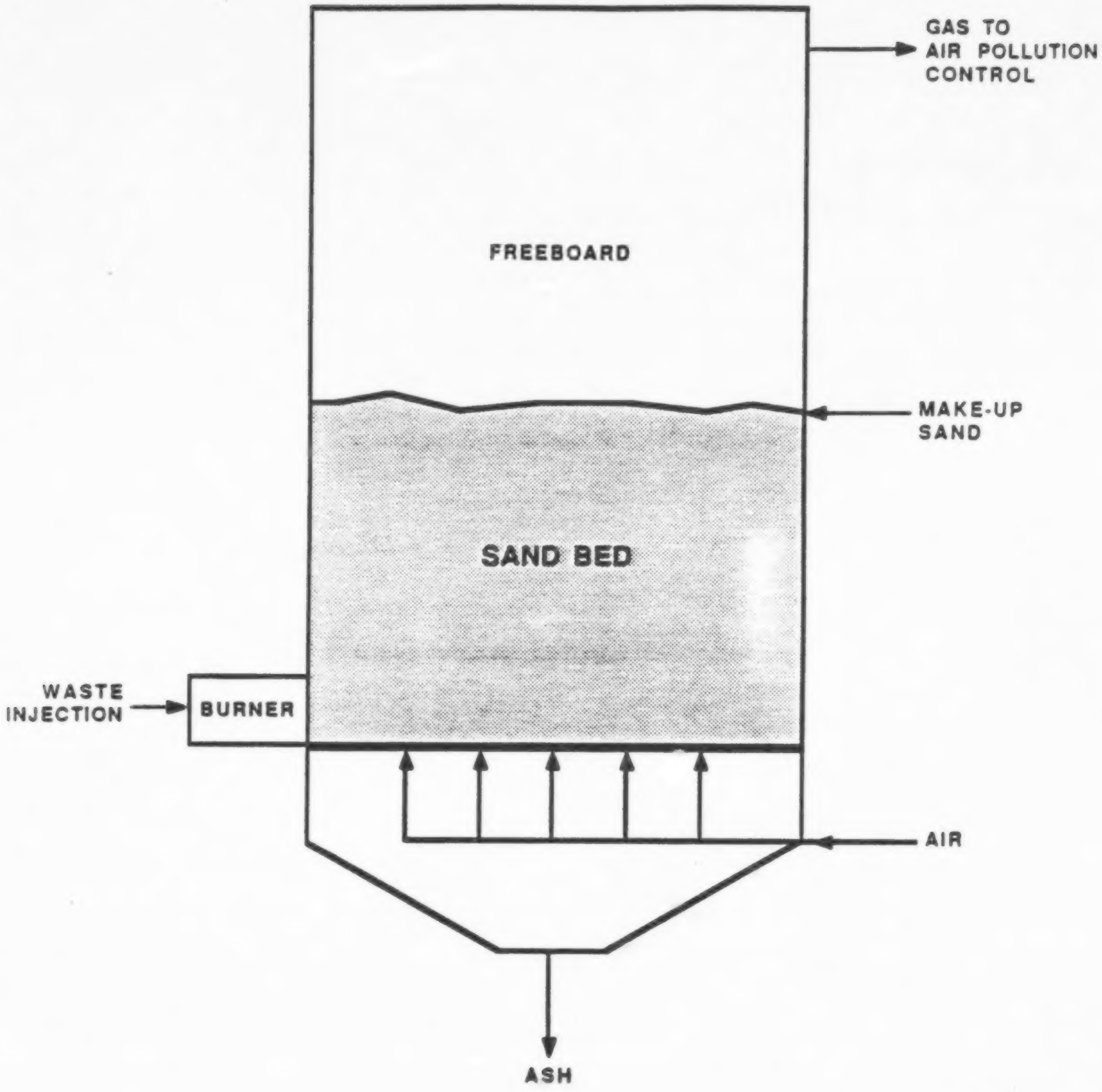

FIGURE 3-3
FLUIDIZED BED INCINERATOR

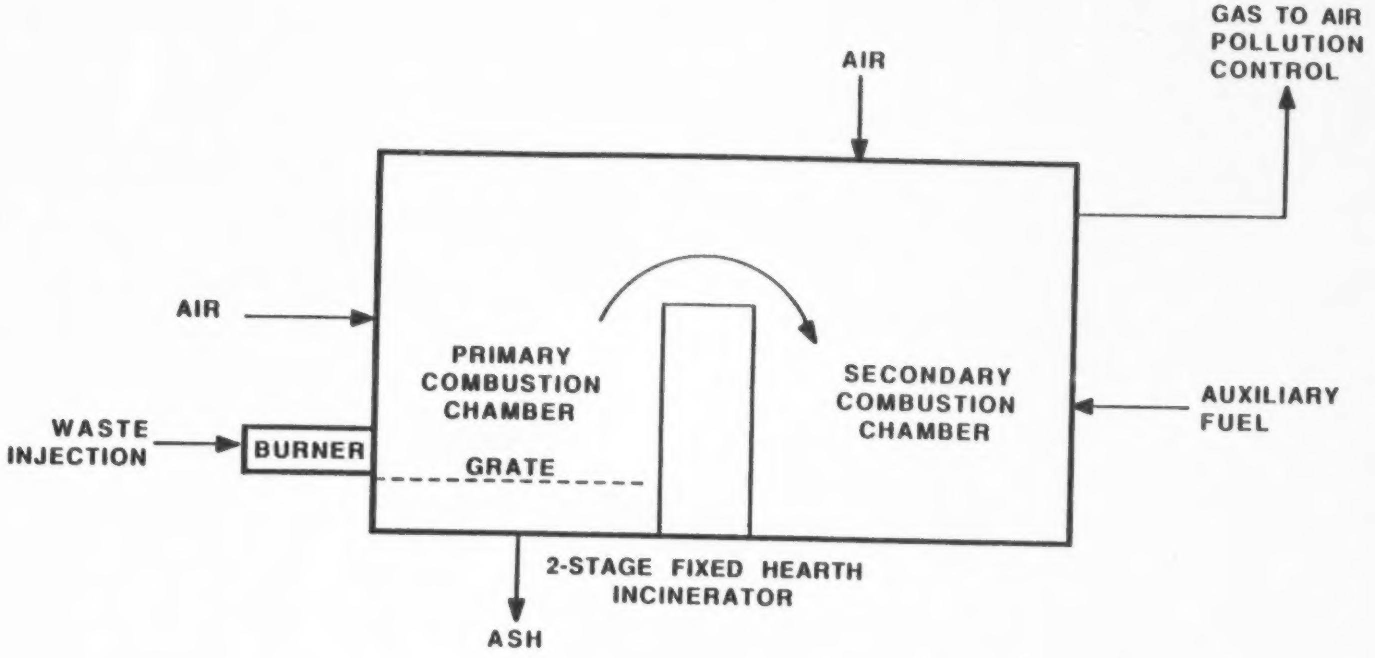

FIGURE 3-4

FIXED HEARTH INCINERATOR

composition, ash will either exit as bottom ash, at the discharge end of a kiln or hearth for example, or as particulate matter (fly ash) suspended in the combustion gas stream. Particulate emissions from most hazardous waste combustion systems generally have particle diameters of less than 1 micron and require high efficiency collection devices to minimize air emissions. In addition, scrubber systems provide an additional buffer against accidental releases of incompletely destroyed waste products resulting from poor combustion efficiency or combustion upsets, such as flameouts.

(4) Waste characteristics affecting performance.

(a) Liquid injection. In determining whether liquid injection is likely to achieve the same level of performance on an untested waste as on a previously tested waste, the Agency will compare the dissociation bond energies of the constituents in the untested and tested wastes. This parameter is being used as a surrogate indicator of activation energy, which, as discussed previously, destabilizes molecular bonds. In theory, the bond dissociation energy would be equal to the activation energy; in practice, however, this is not always the case. Other energy effects (e.g., vibrational, the formation of intermediates, and interactions between different molecular bonds) may have a significant influence on activation energy.

Because of the shortcomings of bond energies in estimating activation energy, EPA analyzed other waste characteristic parameters to determine whether these parameters would provide a better basis for transferring treatment standards from an untested waste to a tested waste. These parameters include heat of combustion, heat of formation, use of available kinetic data to predict activation energies, and general structural class. All of these parameters were rejected for the reasons provided below.

The heat of combustion measures only the difference in energy of the products and reactants; it does not provide information on the transition state. Heat of formation is used as a predictive tool to determine whether reactions are likely to proceed; however, data are not available for a significant number of hazardous constituents. Use of kinetic data was rejected because these data are limited and could not be used to calculate free energy values (ΔG) for the wide range of hazardous constituents to be addressed by this rule. Finally, EPA decided not to use structural classes because the Agency believes that evaluation of bond dissociation energies allows for a more direct determination of whether a constituent will be destabilized.

(b) Rotary kiln/fluidized bed/fixed hearth. Unlike liquid injection, these incineration technologies also generate a residual ash. Accordingly, in determining whether these technologies are likely to achieve the same level of performance on an untested waste as on a previously tested waste, EPA would need to examine the waste characteristics that affect volatilization of organics from the waste, as well as destruction of the organics once volatilized. Relative to volatilization, EPA will examine thermal conductivity of the entire waste and the boiling point of the various constituents. As with liquid injection, EPA will examine bond energies in determining whether treatment standards for scrubber water residuals can be transferred from a tested waste to an untested waste. Below is a discussion of how EPA arrived at thermal conductivity and boiling point as the best method to assess volatilization of organics from the waste; the discussion relative to bond energies is the same for these technologies as for liquid injection and will not be repeated here.

(i) Thermal conductivity. Consistent with the underlying principles of incineration, a major factor with regard to whether a particular constituent will volatilize is the transfer of heat through the waste. In the case of rotary kiln, fluidized bed, and fixed hearth incineration, heat is transferred through the waste by three mechanisms: radiation, convection, and conduction. For a given incinerator, heat transferred through various wastes by radiation is more a function of the design and type of incinerator than the waste being treated. Accordingly, the type of waste treated will have a minimal impact on the amount of heat transferred by radiation. With regard to convection, EPA also believes that the type of heat transfer will generally be more a function of the type and design of the incinerator than the waste itself. However, EPA is examining particle size as a waste characteristic that may significantly impact the amount of heat transferred to a waste by convection and thus impact the volatilization of the various organic compounds. The final type of heat transfer, conduction, is the one that EPA believes will have the greatest impact on volatilization of organic constituents. To measure this characteristic, EPA will use thermal conductivity; an explanation of this parameter, as well as how it can be measured, is provided below.

Heat flow by conduction is proportional to the temperature gradient across the material. The proportionality constant is a property of the material and is referred to as the thermal conductivity. (Note: The analytical method that EPA has identified for measurement of thermal conductivity is named "Guarded, Comparative, Longitudinal Heat Flow Technique"; it is described in Appendix D.) In theory, thermal conductivity would always provide a good indication of whether a constituent in an untested waste would be treated to the same extent in the primary incinerator chamber as the same constituent in a previously tested waste.

In practice, thermal conductivity has some limitations in assessing the transferability of treatment standards; however, EPA has not identified a parameter that can provide a better indication of the heat transfer characteristics of a waste. Below is a discussion of both the limitations associated with thermal conductivity and the other parameters considered.

Thermal conductivity measurements, as part of a treatability comparison for two different wastes through a single incinerator, are most meaningful when applied to wastes that are homogeneous (i.e., major constituents are essentially the same). As wastes exhibit greater degrees of nonhomogeneity (e.g., a significant concentration of metals in soil), then thermal conductivity becomes less accurate in predicting treatability, because the measurement essentially reflects heat flow through regions having the greatest conductivity (i.e., the path of least resistance) and not heat flow through all parts of the waste.

Btu value, specific heat, and ash content were also considered for predicting heat transfer characteristics. These parameters can no better account for nonhomogeneity than can thermal conductivity; additionally, they are not directly related to heat transfer characteristics. Therefore, these parameters do not provide a better indication of heat transfer that will occur in any specific waste.

(ii) Boiling point. Once heat is transferred to a constituent within a waste, removal of this constituent from the waste will depend on its volatility. EPA is using the boiling point as a surrogate of volatility of the constituent. Compounds with lower boiling points have higher vapor pressures and therefore would be more likely to vaporize. The Agency recognizes that this parameter does not take into consideration the impact of other compounds in the waste on the boiling point of a constituent in a mixture; however, the Agency is not aware of a better measure of volatility that can easily be determined.

(5) Design and operating parameters.

(a) Liquid injection. For a liquid injection unit, EPA's analysis of whether the unit is well designed will focus on (1) the likelihood that sufficient energy is provided to the waste to overcome the activation level for breaking molecular bonds, and (2) whether sufficient oxygen is present to convert the waste constituents to carbon dioxide and water vapor. The specific design parameters that the Agency will evaluate to assess whether these conditions are met are temperature, excess oxygen, carbon monoxide level, and waste feed rate. Below is a discussion of why EPA believes these parameters to be important, as well as a discussion of how these parameters will be monitored during operation.

It is important to point out that, relative to the development of land disposal restriction standards, EPA is only concerned with these design parameters when a quench water or scrubber water residual is generated from treatment of a particular waste. If treatment of a particular waste in a liquid injection unit would not generate a wastewater stream, then the Agency, for purposes of land disposal treatment standards, would be concerned solely with the waste characteristics that affect selection of the unit, not with the above-mentioned design parameters.

(i) Temperature. Temperature is important in that it provides an indirect measure of the energy available (i.e., Btu/hr) to overcome the activation energy of waste constituents. As the design temperature increases, it is more likely that the molecular bonds will be destabilized and the reaction completed.

The temperature is normally controlled through the use of instrumentation that senses the temperature and automatically adjusts the amount of fuel and/or waste being fed. The temperature signal transmitted to the controller can be transmitted simultaneously to a recording device, referred to as a strip chart, and thereby continuously recorded. To fully assess the operation of the unit, it is important to know not only the exact location in the incinerator where the temperature is being monitored but also the location of the design temperature.

(ii) Excess oxygen. The incinerator must contain oxygen in excess of the stoichiometric amount needed to convert the organic compounds to carbon dioxide and water vapor. If insufficient oxygen is present, then destabilized waste constituents could recombine to the same or other BDAT list organic compounds and could potentially cause the scrubber water to contain higher concentrations of BDAT list constituents than would be the case for a well-operated unit.

In practice, the amount of oxygen fed to the incinerator is controlled by continuous sampling and analysis of the stack gas. If the amount of oxygen drops below the design value, then the analyzer transmits a signal to the valve controlling the air supply and the flow of oxygen to the afterburner is increased. The analyzer simultaneously transmits a signal to a recording device so that the amount of excess oxygen can be continuously recorded. Again, as with temperature, it is important to know the location from which the combustion gas is being sampled.

(iii) Carbon monoxide. Carbon monoxide is an important operating parameter because it provides an indication of the extent to which the waste organic constituents are being converted to carbon dioxide and water vapor. An increase in the carbon monoxide level indicates that greater amounts of organic waste constituents are unreacted or partially reacted. Increased carbon monoxide levels can result from insufficient excess oxygen, insufficient turbulence in the combustion zone, or insufficient residence time.

(iv) Waste feed rate. The waste feed rate is important to monitor because it is correlated to the residence time. The residence time is associated with a specific Btu energy value of the feed and a specific volume of combustion gas generated. Prior to incineration, the Btu value of the waste is determined through the use of a laboratory device known as a bomb calorimeter. The volume of combustion gas generated from the waste to be incinerated is determined from an analysis referred to as an ultimate analysis. This analysis determines the amount of elemental constituents present, including carbon, hydrogen, sulfur, oxygen, nitrogen, and halogens. Using this analysis plus the total amount of air added, one can calculate the volume of combustion gas. Having determined both the Btu content and the expected combustion gas volume, the feed rate can be fixed at the desired residence time. Continuous monitoring of the feed rate will determine whether the unit was operated at a rate corresponding to the designed residence time.

(b) Rotary kiln. For this incineration technology, EPA will examine both the primary and secondary chamber in evaluating the design of a particular incinerator. Relative to the primary chamber, EPA's assessment of design will focus on whether sufficient energy is likely to be provided to the waste to volatilize the waste constituents. For the secondary chamber, analogous to the sole liquid injection incineration chamber, EPA will examine the same parameters discussed previously under liquid injection incineration. These parameters will not be discussed again here.

The particular design parameters to be evaluated for the primary chamber are kiln temperature, residence time, and revolutions per minute. Below is a discussion of why EPA believes these parameters to be important, as well as a discussion of how these parameters will be monitored during operation.

(i) Temperature. The primary chamber temperature provides an indirect measure of the energy input (i.e., Btu/hr) that is available for heating the waste. The higher the temperature is designed to be in a given kiln, the more likely it is that the constituents will volatilize. As discussed earlier under "Liquid injection," temperature should be continuously monitored and recorded. In addition, it is important to know the location of the temperature sensing device in the kiln.

(ii) Residence time. This parameter affects whether sufficient heat is transferred to a particular constituent to enable volatilization to occur. As the time that the waste is in the kiln is increased, more heat is transferred to the hazardous waste constituents. The residence time will be a function of the specific configuration of the rotary kiln, including the length and diameter of the kiln, the waste feed rate, and the rate of rotation.

(iii) Revolutions per minute (RPM). This parameter provides an indication of the turbulence that occurs in the primary chamber of a rotary kiln. As the turbulence increases, the quantity of heat transferred to the waste would also be expected to increase. As the RPM value increases, however, the residence time decreases, resulting in a reduction of the quantity of heat transferred to the waste. This parameter needs to be carefully evaluated because it provides a balance between turbulence and residence time.

(c) Fluidized bed. As discussed previously in the section on "Underlying principles of operation," the primary chamber accounts for almost all of the conversion of organic wastes to carbon dioxide, water vapor, and acid gas if halogens are present. The secondary chamber will generally provide additional residence time for thermal oxidation of the waste constituents. Relative to the primary chamber, the parameters that the Agency will examine in assessing the effectiveness of the design are temperature, residence time, and bed pressure differential. The first two were discussed under rotary kiln incineration and will not be discussed here. The last, bed pressure differential, is important in that it provides an indication of the amount of turbulence and therefore indirectly the amount of heat supplied to the waste. In general, as the pressure drop increases, both the turbulence and the heat supplied increase. The pressure drop through the bed should be monitored and recorded continuously to ensure that the designed value is achieved.

(d) Fixed hearth. The design considerations for this incineration unit are similar to those for a rotary kiln except that the rate of rotation (i.e., RPM) is not an applicable design parameter. For the primary chamber of this unit, the parameters that the Agency will examine in assessing how well the unit is designed are the same as those discussed under "Rotary kiln"; for the secondary chamber (i.e., afterburner), the design and operating parameters of concern are the same as those discussed under "Liquid injection."

3.2.3 Stabilization

Stabilization refers to a broad class of treatment processes that chemically reduce the mobility of hazardous constituents in a waste. Solidification and fixation are other terms that are sometimes used synonymously for stabilization or to describe specific variations within the broader class of stabilization. Related technologies are encapsulation and thermoplastic binding; however, EPA considers these technologies to be distinct from stabilization in that the operational principles are significantly different.

(1) Applicability and use of stabilization. Stabilization is used when a waste contains metals that will leach from the waste when it is contacted by water. In general, this technology is applicable to wastes containing BDAT list metals having a high filterable solids content, a low TOC content, and a low oil and grease content. This technology is commonly used to treat residuals generated from treatment of electroplating wastewaters. For some wastes, an alternative to stabilization is metal recovery.

(2) Underlying principles of operation. The basic principle underlying this technology is that stabilizing agents and other chemicals are added to a waste to minimize the amount of metal that leaches. The reduced leachability is accomplished by the formation of a lattice structure and/or chemical bonds that bind the metals to the solid matrix and thereby limit the amount of metal constituents that can be leached when water or a mild acid solution comes into contact with the waste material.

Two principal stabilization processes are used -- cement-based and lime-based processes. A brief discussion of each is provided below. In both cement-based and lime/pozzolan-based techniques, the stabilizing process can be modified through the use of additives, such as silicates, that control curing rates or enhance the properties of the solid material.

(a) Portland cement-based process. Portland cement is a mixture of powdered oxides of calcium, silica, aluminum, and iron, produced by kiln burning of materials rich in calcium and silica at high temperatures (i.e., 1,400 to 1,500°C). When the anhydrous cement powder is mixed with water, hydration occurs and the cement begins to set. The chemistry involved is complex because many different reactions occur depending on the composition of the cement mixture.

As the cement begins to set, a colloidal gel of indefinite composition and structure is formed. Over a period of time, the gel swells and forms a matrix composed of interlacing, thin, densely-packed silicate fibrils. Constituents present in the waste slurry (e.g., hydroxides and carbonates of various heavy metals) are incorporated into the interstices of the cement matrix. The high pH of the cement mixture tends to keep metals in the form of insoluble hydroxide and carbonate salts. It has been hypothesized that metal ions may also be incorporated into the crystal structure of the cement matrix, but this hypothesis has not been verified.

(b) Lime/pozzolan-based process. Pozzolan, which contains finely divided, noncrystalline silica (e.g., fly ash or components of cement kiln dust), is a material that is not cementitious in itself, but becomes so upon the addition of lime. Metals in the waste are converted to silicates or hydroxides, which inhibit leaching. Additives, again, can be used to reduce permeability and thereby further decrease leaching potential.

(3) Description of the stabilization process. In most stabilization processes, the waste, stabilizing agent, and other additives, if used, are mixed and then pumped to a curing vessel or area and allowed to cure. The actual operation (equipment requirements and process sequencing) will depend on several factors such as the nature of the waste, the quantity of the waste, the location of the waste in relation to the disposal site, the particular stabilization formulation to be used, and the curing rate. After curing, the solid formed is recovered from the processing equipment and shipped for final disposal.

In instances where waste contained in a lagoon is to be treated, the material should be first transferred to mixing vessels where stabilizing agents are added. The mixed material is then fed to a curing pad or vessel. After curing, the solid formed is removed for disposal. Equipment commonly used also includes facilities to store waste and chemical additives. Pumps can be used to transfer liquid or light sludge wastes to the mixing pits and pumpable uncured wastes to the curing site. Stabilized wastes are then removed to a final disposal site.

Commercial concrete mixing and handling equipment generally can be used with wastes. Weighing conveyors, metering cement hoppers, and mixers similar to concrete batching plants have been adapted in some operations. Where extremely dangerous materials are being treated, remote control and in-drum mixing equipment, such as that used with nuclear waste, can be employed.

(4) Waste characteristics affecting performance. In determining whether stabilization is likely to achieve the same level of performance on an untested waste as on a previously tested waste, the Agency will focus on the characteristics that inhibit the formation of either the chemical bonds or the lattice structure. The four characteristics EPA has identified as affecting treatment performance are the presence of (1) fine particulates, (2) oil and grease, (3) organic compounds, and (4) certain inorganic compounds.

(a) Fine particulates. For both cement-based and lime/pozzolan-based processes, the literature states that very fine solid materials (i.e., those that pass through a No. 200 mesh sieve, 74 um particle size) can weaken the bonding between waste particles and cement by coating the particles. This coating can inhibit chemical bond formation and decreases the resistance of the material to leaching.

(b) Oil and grease. The presence of oil and grease in both cement-based and lime/pozzolan-based systems results in the coating of waste particles and the weakening of the bonding between the particle and the stabilizing agent. This coating can inhibit chemical bond formation and thereby decrease the resistance of the material to leaching.

(c) Organic compounds. The presence of organic compounds in the waste interferes with the chemical reactions and bond formations that inhibit curing of the stabilized material. This results in a stabilized waste having decreased resistance to leaching.

(d) Sulfate and chlorides. The presence of certain inorganic compounds will interfere with the chemical reactions, weakening bond strength and prolonging setting and curing time. Sulfate and chloride compounds may reduce the dimensional stability of the cured matrix, thereby increasing leachability potential.

Accordingly, EPA will examine these constituents when making decisions regarding transfer of treatment standards based on stabilization.

(5) Design and operating parameters. In designing a stabilization system, the principal parameters that are important to optimize so that the amount of leachable metal constituents is minimized are (1) selection of stabilizing agents and other additives, (2) ratio of waste to stabilizing agents and other additives, (3) degree of mixing, and (4) curing conditions.

(a) Selection of stabilizing agents and other additives. The stabilizing agent and additives used will determine the chemistry and structure of the stabilized material and therefore will affect the leachability of the solid material. Stabilizing agents and additives must be carefully selected based on the chemical and physical characteristics of the waste to be stabilized. For example, the amount of sulfates in a waste must be considered when a choice is being made between a lime/pozzolan and a portland cement-based system.

In order to select the type of stabilizing agents and additives, the waste should be tested in the laboratory with a variety of materials to determine the best combination.

(b) Amount of stabilizing agents and additives. The amount of stabilizing agents and additives is a critical parameter since sufficient stabilizing materials are necessary in the mixture to properly bind the waste constituents of concern, making them less susceptible to leaching. The appropriate weight ratios of waste to stabilizing agent and other additives are established empirically by setting up a series of laboratory tests that allow separate leachate testing of different mix ratios. The ratio of water to stabilizing agent (including water in waste) will also impact the strength and leaching characteristics of the stabilized material. Too much water will cause low strength; too little will make mixing difficult and, more important, may not allow the chemical reactions that bind the hazardous constituents to be fully completed.

(c) Mixing. The conditions of mixing include the type and duration of mixing. Mixing is necessary to ensure homogeneous distribution of the waste and the stabilizing agents. Both undermixing and overmixing are undesirable. The first condition results in a nonhomogeneous mixture; therefore, areas will exist within the waste where waste particles are neither chemically bonded to the stabilizing agent nor physically held within the lattice structure. Overmixing, on the other hand, may inhibit gel formation and ion adsorption in some stabilization systems. As with the relative amounts of waste, stabilizing agent, and additives within the system, optimal mixing conditions generally are determined through laboratory tests. During treatment it is important to monitor the degree (i.e., type and duration) of mixing to ensure that it reflects design conditions.

(d) Curing conditions. The curing conditions include the duration of curing and the ambient curing conditions (temperature and humidity). The duration of curing ensures that the waste particles have had sufficient time in which to form stable chemical bonds and/or lattice structures. The time necessary for complete stabilization depends upon the waste type and the stabilization used. The performance of the stabilized waste (i.e., the levels of constituents in the leachate) will be highly dependent upon whether complete stabilization has occurred. Higher temperatures and lower humidity increase the rate of curing by increasing the rate of evaporation of water from the solidification mixtures. If temperatures are too high, however, the evaporation rate can be excessive, resulting in too little water being available for completion of the stabilization reaction. The duration of the curing process should also be determined during the design stage and typically will be between 7 and 28 days.

4. PERFORMANCE DATA BASE

This section discusses the available performance data associated with the demonstrated technologies for K022 waste. Performance data include the constituent concentrations in untreated and treated waste samples, the operating data collected during treatment of the sampled waste, design values for the treatment technology, and data on waste characteristics that affect performance. In this document, EPA has presented all performance data, to the extent that they are available, in tables found at the end of this section.

EPA's use of these data in determining the technology that represents BDAT, and for developing treatment standards, is described in Sections 5 and 7, respectively.

4.1 Nonwastewater

4.1.1 BDAT List Organics

The Agency collected six sets of untreated and treated waste samples from Plant 1 to characterize treatment of K022 using fuel substitution in an industrial boiler. Treatment of K022 resulted in one residual-- the ash, a nonwastewater. The ash, generated during the 24-month period in which the boiler was in service, was collected from the boiler when it was taken out of service for cleaning and maintenance. The Agency believes that the ash is representative of the residual obtained from burning the K022 wastes and other substances that were used as fuels based on information obtained from Plant 1 personnel. Table 4-1 presents the available design data. Table 4-2 contains data for the untreated

K022 waste, while Table 4-3 provides the data for the ash. Since BDAT list organics were not detected in the residual ash, EPA believes that the system was well designed and well operated relative to treatment of this waste. Sufficient QA/QC information is available to adjust the analytical results for the volatile and semivolatile organic constituents in the treated residual data. These data are presented in Appendix B.

From Plant 2, the Agency collected one sample of the untreated waste and six samples of residual ash, also from fuel substitution in an industrial boiler. The sample for the untreated waste is assumed to be representative of the waste burned during the 18-month operation of the boiler. The ash was generated during this period and resulted solely from the combustion of K022 waste. The ash was collected from the boiler when the unit was shut down for cleaning and maintenance. Design data are presented in Table 4-1. Operating data are not available for the industrial boiler used at this facility. Based on the analytical data available for the residual ash, the boiler appeared to have been well operated, since the organic constituents present in the raw waste were reduced to nondetectable levels. Table 4-3 presents the data available for the untreated waste and the residual ash. QA/QC data associated with the treated waste data are limited. The available QA/QC data are presented in Appendix B.

From an industrial boiler at Plant 3, the Agency collected one sample of boiler feed containing a mixture of K022 and other wastes and one sample of the residual ash. (A separate sample of the K022 waste was not collected.) The data obtained for this facility indicated that nondetectable levels for the BDAT organic constituents were achieved. The data, however, are not used to assess the treatment of K022 for three reasons. First, a sample of the K022 waste itself was not obtained; therefore, it is not possible to identify which constituents present in the boiler feed were contributed by the K022 waste and which were contributed by the other wastes also burned in the boiler at the same time. Second, poor recovery values were obtained for the acid fractions of the matrix spike and matrix spike duplicate samples; for example, the recovery value for phenol (a major constituent of K022 waste) in the ash was zero. Therefore, the analytical results could not be adjusted to reflect recoveries. Third, design and operating data for the boiler were not available. As a result, the Agency decided to withdraw these data from further consideration.

4.1.2 BDAT List Metals

EPA does not have performance data showing treatment of BDAT list metals in K022 nonwastewater, i.e., ash. Industry, however, submitted performance data showing treatment of F006 waste (an electroplating sludge) by stabilization, the demonstrated technology for metals in K022 ash. These F006 data, presented in Table 4-5, reflect total and TCLP leachate concentrations for BDAT list metals in the untreated waste and TCLP leachate concentrations for metals in the treated waste. The data represent F006 wastes from various electroplating industries, including auto parts manufacturing, aircraft overhauling, zinc plating, small engine manufacturing, and circuit board manufacturing.

The Agency believes the F006 data can be used to represent the performance of stabilization on the K022 ash. Furthermore, EPA expects that the ash is easier to stabilize because such ash residuals contain metals in the form of oxides, which have been shown to leach at lower concentrations than the typical F006 hydroxides.

Other stabilization data were available to EPA and can be found in the Administrative Record. They were eliminated from further consideration as sources for transferring data to develop treatment standards because of one or a combination of the reasons provided below:

1. The waste treated was less similar to the K022 ash or expected precipitated residuals than the waste for which performance data are presented;
2. The performance data do not show substantial treatment for the constituents to be regulated (selected in Section 6);
3. Design and operating data, or the lack of such data, do not enable the Agency to ascertain whether the treatment system was well designed and well operated; or
4. The measure of performance is not consistent with EPA's approach in evaluating treatment of metals by stabilization; e.g., EP levels rather than TCLP leachate levels are given.

4.2 Wastewater

Data are not available for treatment of K022 wastewater or a waste determined to be similar.

1837g

Table 4-1 Design Data for Use of K022 As Fuel in an Industrial Boiler at Plants 1 and 2

Parameter	Design value	Operating value

This table contains RCRA Confidential Business Information.

Table 4-2 Concentration Data for Untreated K022 Waste at Plant 1

BDAT ref. no.	BDAT list constituent	Untreated waste concentration Sample 1 (mg/kg)	Sample 2 (mg/kg)	Sample 3 (mg/kg)	Sample 4 (mg/kg)	Sample 5 (mg/kg)	Sample 6 (mg/kg)

This table contains RCRA Confidential Business Information.

Table 4-3 Concentration Data for Treated Residual (Ash for K022) at Plant 1

BDAT ref. no.	BDAT list constituent	Waste concentration Sample 1 (mg/kg)	Sample 2 (mg/kg)	Sample 3 (mg/kg)	Sample 4[a] (mg/kg)	Sample 5 (mg/kg)	Sample 6 (mg/kg)
43	Toluene	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012
53	Acetophenone	<3.8	<7.6	<3.8	<3.8	<3.7	<3.8
142	Phenol	<1.9	<3.8	<1.9	<1.9	<1.9	<1.9
106/219	Diphenylamine/ Diphenylnitrosamine	<2.65	<5.3	<2.63	<2.63	<2.6	<2.63
171	Sulfide	200	NA	NA	NA	NA	NA
174	B-BHC	<0.4	NA	NA	NA	NA	NA
181	Dieldrin	<0.4	NA	NA	NA	NA	NA
183	B-Endosulfan	<0.4	NA	NA	NA	NA	NA
155	Arsenic	<15	138	<15	17	<15	45
156	Barium	15	95	28	35	48	27
157	Beryllium	0.1	0.2	<0.1	0.1	<0.1	0.1
158	Cadmium	<2.5	4.1	<2.5	<2.5	<2.5	2.5
159	Chromium	60	289	21	40	26	344
160	Copper	38	2110	<5	12	<5	215
161	Lead	21	1840	<15	<15	<15	105
163	Nickel	47	223	98	161	115	268
166	Thallium	<15	1930	<15	<15	<15	181
167	Vanadium	<5	<5	13	28	18	<5
168	Zinc	25	1740	<2.5	<2.5	<2.5	209
212	Tetrachlorodibenzofuran	0.00035	NA	NA	NA	NA	NA
	TCLP Extract	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
	Barium	0.08	0.066	0.27	0.70	0.29	0.076
	Cadmium	<0.025	<0.025	<0.025	0.074	<0.025	<0.025
	Chromium	0.2	1.3	<0.1	<0.1	0.38	<0.1
	Copper	NA	NA	NA	NA	NA	NA
	Lead	<0.15	<0.15	2.9	132	<0.15	<0.15
	Nickel	NA	NA	NA	NA	NA	NA
	Silver	<0.025	<0.025	<0.025	<0.025	0.029	<0.025
	Zinc	NA	NA	NA	NA	NA	NA

NA = Not analyzed.

[a] Sample 4 TCLP extract was reanalyzed. The results are as follows:

Arsenic - <0.15 mg/l Chromium - 1.7 mg/l
Barium - 0.66 mg/l Lead - <0.15 mg/l
Cadmium - <0.025 mg/l Silver - <0.025 mg/l

Reference: USEPA 1988a.

Table 4-4 Concentration Data for Untreated and Treated Residual K022 Waste at Plant 2

BDAT ref. no.	BDAT list constituent	Concentration						
		Untreated waste[b] (mg/kg)	Treated waste (mg/kg)					
			Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
	Total Composition							
43	Toluene		<0.012	<0.06	<0.012	<0.012	<0.012	<0.012
38	Methylene chloride		<0.008	<0.04	<0.008	<0.008	<0.008	0.021
53	Acetophenone		<1.254	NA	NA	NA	NA	NA
142	Phenol		<0.627	NA	NA	NA	NA	NA
156	Barium		18	21	33	24	23	17
159	Chromium		639	813	1460	753	1050	1540
160	Copper		46	52	50	42	52	55
163	Nickel		278	279	309	284	392	776
167	Vanadium		<5.0	<5.0	<5.0	8.7	<5.0	<5.0
168	Zinc		78	70	56	22	42	77
186	Heptachlor		<0.4	NA	NA	NA	NA	NA
171	Sulfide		320	NA	NA	NA	NA	NA
	TCLP Results[a]							
	Arsenic		<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
	Barium		0.09	0.03	0.1	0.08	0.08	0.14
	Chromium		43	45	66	43	49	47

NA = Not analyzed.

[a] TCLP results are not available for copper, nickel, zinc, and vanadium.
[b] Untreated waste is RCRA Confidential Business Information.

Reference: USEPA 1988b.

Table 4-5 Performance Data for Stabilization of F006 Waste

Constituent	Stream	Concentration (ppm) Sample Set # 1	2	3	4	5	6	7	8	9
Arsenic	Untreated total	-	-	-	-	-	-	-	-	-
	Untreated TCLP	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	0.88
	Treated TCLP[a]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02
	Treated TCLP[b]	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02
Barium	Untreated total	36.4	21.6	85.5	17.2	14.3	24.5	12.6	15.3	19.2
	Untreated TCLP	0.08	0.32	1.41	0.84	0.38	0.07	0.04	0.53	0.28
	Treated TCLP[a]	0.12	0.50	0.33	0.20	0.31	0.30	0.04	0.32	0.19
	Treated TCLP[b]	-	0.42	0.31	0.23	0.19	0.33	0.14	0.27	0.08
Cadmium	Untreated total	1.3	31.3	67.3	1.30	720	7.28	5.39	5.81	5.04
	Untreated TCLP	0.01	2.21	1.13	0.22	23.6	0.3	0.06	0.18	0.01
	Treated TCLP[a]	0.01	0.50	0.06	0.01	3.23	0.02	0.01	0.01	<0.01
	Treated TCLP[b]	-	0.01	0.02	0.01	0.01	0.01	0.01	0.01	<0.01
Chromium	Untreated total	1270	755	716	110	12200	3100	42900	47.9	644
	Untreated TCLP	0.34	0.76	0.43	0.18	25.3	38.7	360	0.04	0.01
	Treated TCLP[a]	0.51	0.40	0.08	0.23	0.25	0.21	3.0	0.10	0.03
	Treated TCLP[b]	-	0.39	0.20	0.30	0.38	0.76	1.21	0.2	0.21
Copper	Untreated total	40.2	7030	693	1510	160	1220	10600	17600	27400
	Untreated TCLP	0.15	368	1.33	4.6	1.14	31.7	8.69	483	16.9
	Treated TCLP[a]	0.20	5.4	1.64	0.30	0.20	0.21	0.40	0.50	3.18
	Treated TCLP[b]	-	0.25	1.84	0.27	0.29	0.20	0.42	0.32	0.46
Lead	Untreated total	35.5	409	25.7	88.5	52	113	156	169	24500
	Untreated TCLP	0.26	10.7	0.26	0.45	0.45	3.37	1.0	4.22	50.2
	Treated TCLP[a]	0.30	0.40	0.30	0.30	0.24	0.30	0.30	0.31	2.39
	Treated TCLP[b]	-	0.36	0.41	0.34	0.36	0.36	0.38	0.37	0.27

Table 4-5 (Continued)

Constituent	Stream	Concentration (ppm) Sample Set # 1	2	3	4	5	6	7	8	9
Mercury	Untreated total	-	-	-	-	-	-	-	-	-
	Untreated TCLP	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001
	Treated TCLP^a	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Treated TCLP^b	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	Untreated total	435	989	259	37	701	19400	13000	23700	5730
	Untreated TCLP	0.71	22.7	1.1	0.52	9.78	730	152	644	16.1
	Treated TCLP^a	0.04	1.5	0.23	0.10	0.53	16.5	0.40	15.7	1.09
	Treated TCLP^b	-	0.03	0.15	0.02	0.04	0.05	0.10	0.04	0.02
Selenium	Untreated total	-	-	-	-	-	-	-	-	-
	Untreated TCLP	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.45
	Treated TCLP^a	0.06	0.06	0.07	0.08	0.04	0.05	0.04	0.07	<0.01
	Treated TCLP^b	-	0.11	0.11	0.14	0.09	0.11	0.07	0.07	<0.01
Silver	Untreated total	2.3	6.62	39	9.05	5.28	4.08	12.5	8.11	19.1
	Untreated TCLP	0.01	0.14	0.02	0.16	0.08	0.12	0.05	0.31	<0.01
	Treated TCLP^a	0.03	0.03	0.20	0.03	0.04	0.03	0.03	0.03	<0.01
	Treated TCLP^b	-	0.05	0.05	0.04	0.06	0.05	0.05	0.05	<0.01
Zinc	Untreated total	1560	4020	631	90200	35900	27800	120	15700	322
	Untreated TCLP	0.16	219	5.41	2030	867	1200	0.62	650	1.29
	Treated TCLP^a	0.03	36.9	0.05	32	3.4	36.3	0.02	4.54	0.07
	Treated TCLP^b	-	0.01	0.03	0.04	0.03	0.04	0.02	0.02	<0.01

Binding agent: cement kiln dust.

[a] Mix ratio is 0.2. The mix ratio is the ratio of the reagent weight to waste weight.

[b] Mix ratio is 0.5.

Note: Waste samples are from the following industries: set #1, unknown; set #2, auto part manufacturing; set #3, aircraft overhauling; set #4, zinc plating; set #5, unknown; set #6, small engine manufacturing; set #7, circuit board manufacturing; set #8, unknown; and set #9, unknown.

Reference: CWM Technical Note 87-117, Table 1. (CWM 1987).

5. IDENTIFICATION OF BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)

This section explains EPA's determination of the best demonstrated available technology (BDAT) for K022 waste. As discussed in Section 1, the BDAT for a waste must be the "best" of the "demonstrated" technologies; the BDAT must also be "available." In general, the technology that constitutes "best" is determined after screening the available data from each demonstrated technology, adjusting these data for accuracy, and comparing the performance of each technology to that of the others. If only one technology is identified as demonstrated, this technology is considered "best." To be "available," a technology (1) must be commercially available and (2) must provide substantial treatment.

5.1 Nonwastewater

5.1.1 BDAT List Organics

While both fuel substitution and incineration are identified as being demonstrated on K022 nonwastewater for treatment of organics, the Agency has performance data for fuel substitution only. Accordingly, it is not possible to perform the statistical comparison test (ANOVA) between these technologies as discussed in Section 1 of this document. While performance data are not available for incineration of K022 waste, EPA would not expect this technology to improve the destruction of BDAT list organic constituents achieved by fuel substitution because the concentrations of the BDAT list organics in the treated waste from fuel substitution are already at nondetectable concentration levels.

Demonstrated technologies are considered "available" if they (1) are commercially available and (2) substantially diminish the toxicity of the waste or substantially reduce the likelihood that hazardous constituents will migrate from the waste. In addition to meeting the criterion of being "commercially available," fuel substitution provides "substantial" treatment by significantly reducing the concentrations of the hazardous organic constituents of concern to nondetectable levels. (See the accuracy-corrected treated waste concentrations in Appendix B.)

Because EPA believes that fuel substitution is "demonstrated," "available," and achieves the "best" performance, the technology is determined to be BDAT for organics in K022 waste.

5.1.2 BDAT List Metals

For metals in K022 nonwastewater, the only identified demonstrated technology is stabilization. Performance data are available for stabilization of F006 waste using cement kiln dust as the binding agent as discussed in Section 4. The Agency does not expect that use of other binders would improve the level of performance. Thus, stabilization using cement kiln dust as the binding agent is "best."

EPA considers stabilization to be "available" as it is commercially available and provides substantial treatment. EPA's determination of substantial treatment is discussed below.

In screening the performance data, the Agency had to determine whether any data points should be deleted because they did not represent a well-designed and well-operated system; thus, EPA deleted data points from the less effective mix ratio used in treating the sample sets. Specifically, EPA determined that a mix ratio of 0.5 was most effective for wastes in sample sets 2, 4, 5, 6, 7, 8, and 9, and that a mix ratio of 0.2 was effective for wastes in sample sets 1 and 3.

The Agency also deleted other data points for individual metal constituents for one of the following reasons: (1) the treated concentration was higher than the untreated concentration; (2) sufficient information was not available on the untreated concentration to determine treatment effectiveness; (3) the untreated leachate concentration was already at a low level where meaningful treatment could not be determined; and (4) after correcting the results for accuracy, the treated level of performance could be attributed solely to dilution from the binding reagent. (Table B-3 shows accuracy-corrected values for all treated waste data points; this table also indicates the specific reasons for data point deletion.)

Table 5-1 shows the remaining data. EPA's determination of substantial treatment is based on observations of the following reductions in the TCLP leachate concentrations of metals in the F006 waste: up to 23 mg/l for cadmium, 358 mg/l for chromium, 49 mg/l for lead, 729 mg/l for nickel, and 0.25 mg/l for silver.

As stabilization using cement kiln dust as a binder is demonstrated, best, and available for BDAT list metals in K022 nonwastewater, stabilization represents BDAT.

5.2 Wastewater

Data and information on treatment of K022 wastewater are not currently available for identifying BDAT.

Table 5-1 TCLP Performance Data for Stabilization of F006 Waste After Screening and Accuracy Correction of Treated Values

Constituent	Stream	Concentration (ppm) Sample Set # 1^a	2^b	3^a	4^b	5^b	6^b	7^b	8^b	9^b
Arsenic	Untreated TCLP	--	--	--	--	--	--	--	--	--
	Treated TCLP	--	--	--	--	--	--	--	--	--
Barium	Untreated TCLP	--	--	1.41	0.84	0.38	--	--	0.53	0.28
	Treated TCLP	--	--	0.34	0.25	0.21	--	--	0.29	0.09
Cadmium	Untreated TCLP	--	2.21	1.13	0.22	23.6	0.3	0.06	0.18	--
	Treated TCLP	--	0.01	0.06	0.01	0.01	0.01	0.01	0.01	--
Chromium	Untreated TCLP	--	0.76	0.43	--	25.3	38.7	360	--	--
	Treated TCLP	--	0.45	0.09	--	0.44	0.89	1.41	--	--
Copper	Untreated TCLP	--	368	--	4.6	1.14	31.7	8.69	483	16.9
	Treated TCLP	--	0.27	--	0.29	0.31	0.22	0.45	0.35	0.50
Lead	Untreated TCLP	--	10.7	--	--	--	3.37	1.0	4.22	50.2
	Treated TCLP	--	0.39	--	--	--	0.39	0.41	0.40	0.29
Mercury	Untreated TCLP	--	--	--	--	--	--	--	--	--
	Treated TCLP	--	--	--	--	--	--	--	--	--
Nickel	Untreated TCLP	0.71	22.7	1.1	0.52	9.78	730	152	644	16.1
	Treated TCLP	0.05	0.03	0.27	0.02	0.04	0.06	0.11	0.04	0.07
Selenium	Untreated TCLP	--	--	--	--	--	--	--	--	--
	Treated TCLP	--	--	--	--	--	--	--	--	--
Silver	Untreated TCLP	--	0.14	--	0.16	--	0.12	--	0.31	--
	Treated TCLP	--	0.06	--	0.05	--	0.06	--	0.06	--
Zinc	Untreated TCLP	0.16	219	5.41	2,030	867	1,200	0.62	650	1.29
	Treated TCLP	0.03	0.01	03	0.04	0.03	0.04	0.02	0.02	0.01

Binding agent: Cement kiln dust.

[a] Mix ratio is 0.2. The mix ratio is the ratio of the reagent weight to waste weight.

[b] Mix ratio is 0.5.

Reference: CWM Technical Note 87-117, Table 1

Since stabilization using cement kiln dust as a binder is best, commercially available, and substantially reduces the likelihood that hazardous metals would leach from the waste, stabilization is determined to be BDAT for the BDAT list metals in K022 nonwastewater.

6. SELECTION OF REGULATED CONSTITUENTS

As discussed in Section 1, the Agency has developed a list of hazardous constituents (see Table 1-1) from which the constituents to be regulated are selected. EPA may revise the list as additional data and information become available. The list is divided into the following categories: volatile organics, semivolatile organics, metals, inorganics, organochlorine pesticides, phenoxyacetic acid herbicides, organophosphorous pesticides, PCBs, and dioxins and furans. The constituents in each category have similar chemical properties and are expected to behave similarly during treatment, with the exception of the inorganics.

This section describes the process used to select the constituents to be regulated. The process involves developing a list of potential regulated constituents and then eliminating those that would not be treated by the chosen BDAT or that would be controlled by regulation of the remaining constituents.

6.1 Identification of BDAT List Constituents in the Untreated Waste

As discussed in Sections 2 and 4, the Agency has characterization data (see Table 2-3) as well as performance data from treatment of K022 waste by fuel substitution (see Tables 4-2, 4-3, and 4-4). These data, along with information on the waste generating process, have been used to determine which BDAT list constituents may be present in the waste and thus which are potential candidates for regulation in the nonwastewater and wastewater.

Table 6-1 indicates, for the untreated waste, which constituents were analyzed, which constituents were detected, and which constituents the Agency believes could be present but not detected. For those constituents detected, concentrations are indicated.

Under the column "Believed to be present," constituents other than those detected in the untreated waste are marked with X or Y if EPA believes they are likely to be present in the untreated waste. For those constituents marked with X, an engineering analysis of the waste generating process indicated that they are likely to be present (e.g., the engineering analysis shows that a particular constituent is present in the raw material). Those constituents marked with Y have been detected in the treated residual(s), and thus EPA believes they are present in the untreated waste. Constituents may not have been detected in the untreated waste for one of several reasons: (1) none of the untreated waste samples were analyzed for those constituents, (2) masking or interference by other constituents prevented detection, or (3) the constituent indeed was not present. It is important to note that some wastes are defined as being generated from a process that may utilize variable raw materials composed of different constituents. Therefore, all potentially regulated constituents would not necessarily be present in any given sample.

As shown on Table 6-1, K022 samples were analyzed for 214 of the 231 BDAT list constituents. Because there is no in-process source for the remaining 17 constituents, EPA believes they are unlikely to be present.

Of the 214 constituents analyzed, 14 were detected in untreated waste samples. These include four volatile organics, four semivolatile organics, chromium, sulfide, and four organochlorine pesticides. Ten additional metals and one polychlorinated furan were found in the treated residuals and therefore are believed to be present in the waste. These 25 constituents are potential candidates for regulation.

6.2 Constituent Selection

EPA has chosen to regulate one volatile organic, all four semivolatile organics, and two metals. These constituents are presented in Table 6-2. Two of the semivolatile organics--diphenylamine and diphenylnitrosamine--are regulated as the sum of these constituents because these two compounds cannot be distinguished using EPA's standard analytical testing procedures.

Of the three volatiles detected in the untreated waste (toluene, ethyl benzene, and methylene chloride), the Agency selected toluene. Methylene chloride is present in the untreated waste at lower concentrations according to the data, and the compound is expected to be easier to treat based on its boiling point (40 to 42°C for methylene chloride versus 111°C for toluene). Ethyl benzene is not being regulated because treatment data for this constituent are not available. (The treated residual ash was not analyzed for this constituent and other data are not available for transferring.)

Of the metals, chromium and nickel are present in the ash at the highest concentrations for most of the ash samples relative to the other metals detected. The Agency believes that stabilization of chromium and nickel is necessary to reduce the leachability of these two constituents in the ash. Also, the Agency believes that stabilization of these two BDAT list metals will reduce the leachability of the remaining BDAT list metals present in the ash residual.

The four pesticides, B-BHC, dieldrin, B-endosulfan, and heptachlor, were not selected for regulation because (1) they are present at concentrations significantly lower than the volatiles and semivolatile organics, and (2) it is believed that they will be treated along with the regulated constituent based on their relatively low initial concentrations.

Sulfide is not being regulated at this time as the Agency currently has not completed its evaluation of its waste characterization and treatment information. Tetrachlorodibenzofurans are not being regulated at this time because the accuracy of the quantification for the constituent cannot be determined. EPA has concluded that additional analysis, with the proper QA/QC, would be required before EPA can consider developing treatment standards for the constituent.

Table 6-1 Status of BDAT List Constituent Presence in Untreated K022 Waste

BDAT reference no.	Constituent	Detection status^a	Believed to be present
	Volatile organics		
222.	Acetone	D (CBI)	
1.	Acetonitrile	ND	
2.	Acrolein	ND	
3.	Acrylonitrile	ND	
4.	Benzene	ND	
5.	Bromodichloromethane	ND	
6.	Bromomethane	ND	
223.	n-Butyl alcohol	NA	
7.	Carbon tetrachloride	ND	
8.	Carbon disulfide	ND	
9.	Chlorobenzene	ND	
10.	2-Chloro-1,3-butadiene	ND	
11.	Chlorodibromomethane	ND	
12.	Chloroethane	ND	
13.	2-Chloroethyl vinyl ether	ND	
14.	Chloroform	ND	
15.	Chloromethane	ND	
16.	3-Chloropropene	ND	
17.	1,2-Dibromo-3-chloropropane	ND	
18.	1,2-Dibromoethane	ND	
19.	Dibromomethane	ND	
20.	trans-1,4-Dichloro-2-butene	ND	
21.	Dichlorodifluoromethane	ND	
22.	1,1-Dichloroethane	ND	
23.	1,2-Dichloroethane	ND	
24.	1,1-Dichloroethylene	ND	
25.	trans-1,2-Dichloroethene	ND	
26.	1,2-Dichloropropane	ND	
27.	trans-1,3-Dichloropropene	ND	
28.	cis-1,3-Dichloropropene	ND	
29.	1,4-Dioxane	ND	
224.	2-Ethoxyethanol	NA	
225.	Ethyl acetate	NA	
226.	Ethyl benzene	D (CBI)	
30.	Ethyl cyanide	ND	
227.	Ethyl ether	NA	
31.	Ethyl methacrylate	ND	
214.	Ethylene oxide	NA	
32.	Iodomethane	ND	
33.	Isobutyl alcohol	ND	
228.	Methanol	NA	
34.	Methyl ethyl ketone	ND	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Volatile organics (continued)		
229.	Methyl isobutyl ketone	NA	
35.	Methyl methacrylate	ND	
37.	Methacrylonitrile	ND	
38.	Methylene chloride	D (CBI)	
230.	2-Nitropropane	NA	
39.	Pyridine	ND	
40.	1,1,1,2-Tetrachloroethane	ND	
41.	1,1,2,2-Tetrachloroethane	ND	
42.	Tetrachloroethene	ND	
43.	Toluene	D (CBI)	
44.	Tribromomethane	ND	
45.	1,1,1-Trichloroethane	ND	
46.	1,1,2-Trichloroethane	ND	
47.	Trichloroethene	ND	
48.	Trichloromonofluoromethane	ND	
49.	1,2,3-Trichloropropane	ND	
231.	1,1,2-Trichloro-1,2,2-trifluoroethane	NA	
50.	Vinyl chloride	ND	
215.	1,2-Xylene	NA	
216.	1,3-Xylene	NA	
217.	1,4-Xylene	NA	
	Semivolatile organics		
51.	Acenaphthalene	ND	
52.	Acenaphthene	ND	
53.	Acetophenone	D (CBI)	
54.	2-Acetylaminofluorene	ND	
55.	4-Aminobiphenyl	ND	
56.	Aniline	ND	
57.	Anthracene	ND	
58.	Aramite	ND	
59.	Benz(a)anthracene	ND	
218.	Benzal chloride	NA	
60.	Benzenethiol	ND	
61.	Deleted		
62.	Benzo(a)pyrene	ND	
63.	Benzo(b)fluoranthene	ND	
64.	Benzo(ghi)perylene	ND	
65.	Benzo(k)fluoranthene	ND	
66.	p-Benzoquinone	ND	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Semivolatile organics (continued)		
67.	Bis(2-chloroethoxy)methane	ND	
68.	Bis(2-chloroethyl)ether	ND	
69.	Bis(2-chloroisopropyl)ether	ND	
70.	Bis(2-ethylhexyl)phthalate	ND	
71.	4-Bromophenyl phenyl ether	ND	
72.	Butyl benzyl phthalate	ND	
73.	2-sec-Butyl-4,6-dinitrophenol	ND	
74.	p-Chloroaniline	ND	
75.	Chlorobenzilate	ND	
76.	p-Chloro-m-cresol	ND	
77.	2-Chloronaphthalene	ND	
78.	2-Chlorophenol	ND	
79.	3-Chloropropionitrile	ND	
80.	Chrysene	ND	
81.	ortho-Cresol	ND	
82.	para-Cresol	ND	
232.	Cyclohexanone	NA	
83.	Dibenz(a,h)anthracene	ND	
84.	Dibenzo(a,e)pyrene	ND	
85.	Dibenzo(a,i)pyrene	ND	
86.	m-Dichlorobenzene	ND	
87.	o-Dichlorobenzene	ND	
88.	p-Dichlorobenzene	ND	
89.	3,3'-Dichlorobenzidine	ND	
90.	2,4-Dichlorophenol	ND	
91.	2,6-Dichlorophenol	ND	
92.	Diethyl phthalate	ND	
93.	3,3'-Dimethoxybenzidine	ND	
94.	p-Dimethylaminoazobenzene	ND	
95.	3,3'-Dimethylbenzidine	ND	
96.	2,4-Dimethylphenol	ND	
97.	Dimethyl phthalate	ND	
98.	Di-n-butyl phthalate	ND	
99.	1,4-Dinitrobenzene	ND	
100.	4,6-Dinitro-o-cresol	ND	
101.	2,4-Dinitrophenol	ND	
102.	2,4-Dinitrotoluene	ND	
103.	2,6-Dinitrotoluene	ND	
104.	Di-n-octyl phthalate	ND	
105.	Di-n-propylnitrosamine	ND	
106./219.	Diphenylamine Diphenylnitrosamine	D (CBI)	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status^{a}	Believed to be present
	Semivolatile organics (continued)		
107.	1,2-Diphenylhydrazine	ND	
108.	Fluoranthene	ND	
109.	Fluorene	ND	
110.	Hexachlorobenzene	ND	
111.	Hexachlorobutadiene	ND	
112.	Hexachlorocyclopentadiene	ND	
113.	Hexachloroethane	ND	
114.	Hexachlorophene	ND	
115.	Hexachloropropene	ND	
116.	Indeno(1,2,3-cd)pyrene	ND	
117.	Isosafrole	ND	
118.	Methapyrilene	ND	
119.	3-Methylcholanthrene	ND	
120.	4,4'-Methylenebis (2-chloroaniline)	ND	
36.	Methyl methanesulfonate	ND	
121.	Naphthalene	ND	
122.	1,4-Naphthoquinone	ND	
123.	1-Naphthylamine	ND	
124.	2-Naphthylamine	ND	
125.	p-Nitroaniline	ND	
126.	Nitrobenzene	ND	
127.	4-Nitrophenol	ND	
128.	N-Nitrosodi-n-butylamine	ND	
129.	N-Nitrosodiethylamine	ND	
130.	N-Nitrosodimethylamine	ND	
131.	N-Nitrosomethylethylamine	ND	
132.	N-Nitrosomorpholine	ND	
133.	N-Nitrosopiperidine	ND	
134.	n-Nitrosopyrrolidine	ND	
135.	5-Nitro-o-toluidine	ND	
136.	Pentachlorobenzene	ND	
137.	Pentachloroethane	ND	
138.	Pentachloronitrobenzene	ND	
139.	Pentachlorophenol	ND	
140.	Phenacetin	ND	
141.	Phenanthrene	ND	
142.	Phenol	D (CBI)	
220.	Phthalic anhydride	NA	
143.	2-Picoline	ND	
144.	Pronamide	ND	
145.	Pyrene	ND	
146.	Resorcinol	ND	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Semivolatile organics (continued)		
147.	Safrole	ND	
148.	1,2,4,5-Tetrachlorobenzene	ND	
149.	2,3,4,6-Tetrachlorophenol	ND	
150.	1,2,4-Trichlorobenzene	ND	
151.	2,4,5-Trichlorophenol	ND	
152.	2,4,6-Trichlorophenol	ND	
153.	Tris(2,3-dibromopropyl) phosphate	ND	
	Metals		
154.	Antimony	ND	
155.	Arsenic	ND	Y
156.	Barium	ND	Y
157.	Beryllium	ND	Y
158.	Cadmium	ND	Y
159.	Chromium (total)	D (CBI)	
221.	Chromium (hexavalent)	NA	
160.	Copper	ND	Y
161.	Lead	ND	Y
162.	Mercury	ND	
163.	Nickel	ND	Y
164.	Selenium	ND	
165.	Silver	ND	
166.	Thallium	ND	Y
167.	Vanadium	ND	Y
168.	Zinc	ND	Y
	Inorganics other than metals		
169.	Cyanide	ND	
170.	Fluoride	D (CBI)	
171.	Sulfide	D (CBI)	
	Organochlorine pesticides		
172.	Aldrin	ND	
173.	alpha-BHC	ND	
174.	beta-BHC	D (CBI)	
175.	delta-BHC	ND	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Organochlorine pesticides (continued)		
176.	gamma-BHC	ND	
177.	Chlordane	ND	
178.	DDD	ND	
179.	DDE	ND	
180.	DDT	ND	
181.	Dieldrin	D (CBI)	
182.	Endosulfan I	ND	
183.	Endosulfan II	D (CBI)	
184.	Endrin	ND	
185.	Endrin aldehyde	ND	
186.	Heptachlor	D (CBI)	
187.	Heptachlor epoxide	ND	
188.	Isodrin	ND	
189.	Kepone	ND	
190.	Methoxyclor	ND	
191.	Toxaphene	ND	
	Phenoxyacetic acid herbicides		
192.	2,4-Dichlorophenoxyacetic acid	ND	
193.	Silvex	ND	
194.	2,4,5-T	ND	
	Organophosphorous insecticides		
195.	Disulfoton	ND	
196.	Famphur	ND	
197.	Methyl parathion	ND	
198.	Parathion	ND	
199.	Phorate	ND	
	PCBs		
200.	Aroclor 1016	ND	
201.	Aroclor 1221	ND	
202.	Aroclor 1232	ND	
203.	Aroclor 1242	ND	
204.	Aroclor 1248	ND	
205.	Aroclor 1254	ND	
206.	Aroclor 1260	ND	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Dioxins and furans		
207.	Hexachlorodibenzo-p-dioxins	ND	
208.	Hexachlorodibenzofurans	ND	
209.	Pentachlorodibenzo-p-dioxins	ND	
210.	Pentachlorodibenzofurans	ND	
211.	Tetrachlorodibenzo-p-dioxins	ND	
212.	Tetrachlorodibenzofurans	D (CBI)	
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin	ND	

D = Detected.

CBI = Confidential business information.

ND = Not detected.

NA = Not analyzed.

X = Believed to be present based on engineering analysis of waste generating process.

Y = Believed to be present based on detection in treated residuals.

[a] If detected, concentration is shown, units are mg/kg.

Table 6-2 Regulated Constituents for K022 Waste

BDAT Volatile Organics

Toluene

BDAT Semivolatile Organics

Acetophenone
Phenol
Sum of Diphenylamine and
  Diphenylnitrosamine[a]

BDAT Metals

Chromium
Nickel

---

[a] The standard for diphenylamine and diphenylnitrosamine will be calculated as the sum of these two constituents because the two constituents cannot be distinguished using EPA's standard analytical testing procedure.

7. CALCULATION OF BDAT TREATMENT STANDARDS

This section details the calculation of treatment standards for the regulated constituents selected in Section 6. EPA is setting nonwastewater treatment standards based on performance data from (1) fuel substitution and (2) stabilization, using a cement kiln dust binder of a nonwastewater similar to the ash residual generated from use of K022 as a fuel substitute.

7.1 Nonwastewater

For treatment of BDAT list organics in K022 nonwastewater by fuel substitution, all six data sets from Plant 1 have been used to calculate the treatment standards. The treatment data from this plant are believed to represent a well-designed and well-operated treatment system, since the organic constituents present in the untreated wastes were reduced to nondetectable levels in the treatment residual. Furthermore, they are accompanied by sufficient QA/QC data to develop treatment standards. Thus, the data points meet the requirements for setting treatment standards. The data from Plant 2 have not been used because sufficient QA/QC data are not available to adjust the data for accuracy.

Five of the data points from stabilization of F006 waste show treatment of chromium; nine data points show treatment of nickel. These data points were used to calculate the metal treatment standards for K022 waste. The performance data from stabilization of the F006 waste using a cement kiln dust binder reflect treatment in a well-designed, well-operated system; the data also are accompanied by sufficient QA/QC information. Thus, the data meet the requirements for setting treatment standards.

As discussed in Section 1, the calculation of a treatment standard for a constituent to be regulated involves (1) adjusting the data points for accuracy, (2) determining the mean (arithmetic average) and variability factor (see Appendix A) for the data points, and (3) multiplying the mean and the variability factor together to determine the treatment standard.

The procedure for adjusting the data points is discussed in detail in Section 1. The data from each of the demonstrated technologies are adjusted in Appendix B. The unadjusted and accuracy-corrected values for the regulated constituents are presented again in Tables 7-1 and 7-2, along with the accuracy-correction factors, means of the accuracy-corrected values, and treatment standards.

7.2 Wastewater

As discussed in Section 3, the Agency is aware that K022 wastewater is generated from treatment of K022 waste. Since neither characterization data nor treatment data are available for such wastewater, the Agency has not identified technologies that would be demonstrated for the waste or developed treatment standards for the waste. EPA intends to propose and promulgate treatment standards for K022 wastewater prior to May 8, 1990.

Table 7-1 Calculation of Nonwastewater Treatment Standards for the Regulated Constituents Treated by Fuel Substitution

	Unadjusted concentration (mg/kg) Sample Set #						Correction factor	Accuracy-corrected concentration (mg/kg) Sample Set #						Mean (mg/kg)	Variability factor	Treatment standard (mg/kg)
	1	2	3	4	5	6		1	2	3	4	5	6			
BDAT Volatile Organics																
Toluene	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	1.0	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	2.8	0.034
BDAT Semivolatile Organics																
Acetophenone	<3.8	<7.6	<3.8	<3.8	<3.7	<3.8	1/0.65	<5.8	<11.69	<5.8	<5.8	<5.7	<5.8	6.77	2.8	19
Phenol	<1.9	<3.8	<1.9	<1.9	<1.9	<1.9	1/0.51	<3.7	<7.25	<3.7	<3.7	<3.7	<3.7	4.29	2.8	12
Diphenylamine/ Diphenylnitrosamine	<2.65	<5.3	<2.63	<2.63	<2.6	<2.63	1/0.65	<4.1	<8.2	<4.1	<4.1	<4.0	<4.1	4.77	2.8	13

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Table 7-2 Calculation of Nonwastewater Treatment Standards for the Regulated Constituents Treated by Stabilization

	Chromium			Nickel		
	TCLP concentration (mg/l)	Correction factor	Accuracy-corrected value (mg/l)	TCLP concentration (mg/l)	Correction factor	Accuracy-corrected value (mg/l)
Sample Set #1	-	-	-	0.04	1/0.866	0.046
Sample Set #2	0.39	1/0.858	0.454	0.03	1/0.903	0.033
Sample Set #3	0.08	1/0.866	0.092	0.23	1/0.866	0.266
Sample Set #4	-	-	-	0.02	1/0.903	0.022
Sample Set #5	0.38	1/0.858	0.443	0.04	1/0.903	0.044
Sample Set #6	0.76	1/0.858	0.886	0.05	1/0.903	0.055
Sample Set #7	1.21	1/0.858	1.41	0.10	1/0.903	0.111
Sample Set #8	-	-	-	0.04	1/0.903	0.044
Sample Set #9	-	-	-	0.02	1/0.903	0.022
Average (mg/l)			0.657			0.072
Sample no.			5			9
Variability factor			7.94			4.47
Treatment standard (mg/l)			5.2			0.32

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APPENDIX A

STATISTICAL METHODS

A.1 F Value Determination for ANOVA Test

As noted in Section 1.2, EPA is using the statistical method known as analysis of variance (ANOVA) to determine the level of performance that represents "best" treatment where more than one technology is demonstrated. This method provides a measure of the differences between data sets.

If the Agency found that the levels of performance for one or more technologies are not statistically different (i.e., the data sets are homogeneous), EPA would average the long-term performance values achieved by each technology and then multiply this value by the largest variability factor associated with any of the acceptable technologies. If EPA found that one technology performs significantly better (i.e., the data sets are not homogeneous), the "best" technology would be the technology that achieves the best level of performance, i.e., the technology with the lowest mean value.

To determine whether any or all of the treatment performance data sets are homogeneous using the analysis of variance method, it is necessary to compare a calculated "F value" to what is known as a "critical value." (See Table A-1.) These critical values are available in most statistics texts (see, for example, Statistical Concepts and Methods by Bhattacharyya and Johnson, 1977, John Wiley Publications, New York).

Table A-1

95th PERCENTILE VALUES FOR THE F DISTRIBUTION

n_1 = degrees of freedom for numerator
n_2 = degrees of freedom for denominator
(shaded area = .95)

n_2 \ n_1	1	2	3	4	5	6	8	12	16	20	30	40	50	100	∞
1	161.4	199.5	215.7	224.6	230.2	234.0	238.9	243.9	246.3	248.0	250.1	251.1	252.2	253.0	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.37	19.41	19.43	19.45	19.46	19.46	19.47	19.49	19.50
3	10.13	9.55	9.28	9.12	9.01	8.94	8.85	8.74	8.69	8.66	8.62	8.60	8.58	8.56	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.04	5.91	5.84	5.80	5.75	5.71	5.70	5.66	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.82	4.68	4.60	4.56	4.50	4.46	4.44	4.40	4.36
6	5.99	5.14	4.76	4.53	4.39	4.28	4.15	4.00	3.92	3.87	3.81	3.77	3.75	3.71	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.73	3.57	3.49	3.44	3.38	3.34	3.32	3.28	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.44	3.28	3.20	3.15	3.08	3.05	3.03	2.98	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.23	3.07	2.98	2.93	2.86	2.82	2.80	2.76	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.07	2.91	2.82	2.77	2.70	2.67	2.64	2.59	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	2.95	2.79	2.70	2.65	2.57	2.53	2.50	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.85	2.69	2.60	2.54	2.46	2.42	2.40	2.35	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.77	2.60	2.51	2.46	2.38	2.34	2.32	2.26	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.70	2.53	2.44	2.39	2.31	2.27	2.24	2.19	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.64	2.48	2.39	2.33	2.25	2.21	2.18	2.12	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.59	2.42	2.33	2.28	2.20	2.16	2.13	2.07	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.55	2.38	2.29	2.23	2.15	2.11	2.08	2.02	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.51	2.34	2.25	2.19	2.11	2.07	2.04	1.98	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.48	2.31	2.21	2.15	2.07	2.02	2.00	1.94	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.45	2.28	2.18	2.12	2.04	1.99	1.96	1.90	1.84
22	4.30	3.44	3.05	2.82	2.66	2.55	2.40	2.23	2.13	2.07	1.98	1.93	1.91	1.84	1.78
24	4.26	3.40	3.01	2.78	2.62	2.51	2.36	2.18	2.09	2.03	1.94	1.89	1.86	1.80	1.73
26	4.23	3.37	2.98	2.74	2.59	2.47	2.32	2.15	2.05	1.99	1.90	1.85	1.82	1.76	1.69
28	4.20	3.34	2.95	2.71	2.56	2.45	2.29	2.12	2.02	1.96	1.87	1.81	1.78	1.72	1.65
30	4.17	3.32	2.92	2.69	2.53	2.42	2.27	2.09	1.99	1.93	1.84	1.79	1.76	1.69	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.18	2.00	1.90	1.84	1.74	1.69	1.66	1.59	1.51
50	4.03	3.18	2.79	2.56	2.40	2.29	2.13	1.95	1.85	1.78	1.69	1.63	1.60	1.52	1.44
60	4.00	3.15	2.76	2.53	2.37	2.25	2.10	1.92	1.81	1.75	1.65	1.59	1.56	1.48	1.39
70	3.98	3.13	2.74	2.50	2.35	2.23	2.07	1.89	1.79	1.72	1.62	1.56	1.53	1.45	1.35
80	3.96	3.11	2.72	2.48	2.33	2.21	2.05	1.88	1.77	1.70	1.60	1.54	1.51	1.42	1.32
100	3.94	3.09	2.70	2.46	2.30	2.19	2.03	1.85	1.75	1.68	1.57	1.51	1.48	1.39	1.28
150	3.91	3.06	2.67	2.43	2.27	2.16	2.00	1.82	1.71	1.64	1.54	1.47	1.44	1.34	1.22
200	3.89	3.04	2.65	2.41	2.26	2.14	1.98	1.80	1.69	1.62	1.52	1.45	1.42	1.32	1.19
400	3.86	3.02	2.62	2.39	2.23	2.12	1.96	1.78	1.67	1.60	1.49	1.42	1.38	1.28	1.13
∞	3.84	2.99	2.60	2.37	2.21	2.09	1.94	1.75	1.64	1.57	1.46	1.40	1.32	1.24	1.00

Where the F value is less than the critical value, all treatment data sets are homogeneous. If the F value exceeds the critical value, it is necessary to perform a "pair wise F" test to determine if any of the sets are homogeneous. The "pair wise F" test must be done for all of the various combinations of data sets using the same method and equation as the general F test.

The F value is calculated as follows:

(i) All data are natural logtransformed.

(ii) The sum of the data points for each data set is computed (T_i).

(iii) The statistical parameter known as the sum of the squares between data sets (SSB) is computed:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

where:

k = number of treatment technologies
n_i = number of data points for technology i
N = number of data points for all technologies
T_i = sum of natural logtransformed data points for each technology.

(iv) The sum of the squares within data sets (SSW) is computed:

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

where:

$x_{i,j}$ = the natural logtransformed observations (j) for treatment technology (i).

(v) The degrees of freedom corresponding to SSB and SSW are calculated. For SSB, the degree of freedom is given by k-1. For SSW, the degree of freedom is given by N-k.

(vi) Using the above parameters, the F value is calculated as follows:

$$F = \frac{MSB}{MSW}$$

where:

$MSB = SSB/(k-1)$ and
$MSW = SSW/(N-k)$.

A computational table summarizing the above parameters is shown below.

Computational Table for the F Value

Source	Degrees of freedom	Sum of squares	Mean square	F value
Between	k-1	SSB	MSB = SSB/k-1	MSB/MSW
Within	N-k	SSW	MSW = SSW/N-k	

Below are three examples of the ANOVA calculation. The first two represent treatment by different technologies that achieve statistically similar treatment; the last example represents a case in which one technology achieves significantly better treatment than the other technology.

Example 1
Methylene Chloride

	Steam stripping				Biological treatment		
Influent (μg/l)	Effluent (μg/l)	ln(effluent)	$[\ln(\text{effluent})]^2$	Influent (μg/l)	Effluent (μg/l)	ln(effluent)	$[\ln(\text{effluent})]^2$
1550.00	10.00	2.30	5.29	1960.00	10.00	2.30	5.29
1290.00	10.00	2.30	5.29	2568.00	10.00	2.30	5.29
1640.00	10.00	2.30	5.29	1817.00	10.00	2.30	5.29
5100.00	12.00	2.48	6.15	1640.00	26.00	3.26	10.63
1450.00	10.00	2.30	5.29	3907.00	10.00	2.30	5.29
4600.00	10.00	2.30	5.29				
1760.00	10.00	2.30	5.29				
2400.00	10.00	2.30	5.29				
4800.00	10.00	2.30	5.29				
12100.00	10.00	2.30	5.29				
Sum:							
-		23.18	53.76	-	-	12.46	31.79
Sample Size:							
10	10	10	-	5	5	5	-
Mean:							
3669	10.2	2.32	-	2378	13.2	2.49	-
Standard Deviation:							
3328.67	.63	.06	-	923.04	7.15	.43	-
Variability Factor:							
	1.15	-	-	-	2.48	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

$$MSB = SSB/(k-1)$$

$$MSW = SSW/(N-k)$$

Example 1 (Continued)

$F = MSB/MSW$

where:

k = number of treatment technologies

n_i = number of data points for technology i

N = number of natural logtransformed data points for all technologies

T_i = sum of logtransformed data points for each technology

X_{ij} - the nat. logtransformed observations (j) for treatment technology (i)

$n_1 = 10$, $n_2 = 5$, $N = 15$, $k = 2$, $T_1 = 23.18$, $T_2 = 12.46$, $T = 35.64$, $T^2 = 1270.21$

$T_1^2 = 537.31$ $T_2^2 = 155.25$

$$SSB = \left(\frac{537.31}{10} + \frac{155.25}{5}\right) - \frac{1270.21}{15} = 0.10$$

$$SSW = (53.76 + 31.79) - \left(\frac{537.31}{10} + \frac{155.25}{5}\right) = 0.77$$

$MSB = 0.10/1 = 0.10$

$MSW = 0.77/13 = 0.06$

$$F = \frac{0.10}{0.06} = 1.67$$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	0.10	0.10	1.67
Within(W)	13	0.77	0.06	

The critical value of the F test at the 0.05 significance level is 4.67. Since the F value is less than the critical value, the means are not significantly different (i.e., they are homogeneous).

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

Example 2
Trichloroethylene

Steam stripping Influent (μg/l)	Effluent (μg/l)	ln(effluent)	$[\ln(\text{effluent})]^2$	Biological treatment Influent (μg/l)	Effluent (μg/l)	ln(effluent)	$[\ln(\text{effluent})]^2$
1650.00	10.00	2.30	5.29	200.00	10.00	2.30	5.29
5200.00	10.00	2.30	5.29	224.00	10.00	2.30	5.29
5000.00	10.00	2.30	5.29	134.00	10.00	2.30	5.29
1720.00	10.00	2.30	5.29	150.00	10.00	2.30	5.29
1560.00	10.00	2.30	5.29	484.00	16.25	2.79	7.78
10300.00	10.00	2.30	5.29	163.00	10.00	2.30	5.29
210.00	10.00	2.30	5.29	182.00	10.00	2.30	5.29
1600.00	27.00	3.30	10.89				
204.00	85.00	4.44	19.71				
160.00	10.00	2.30	5.29				
Sum:							
-	-	26.14	72.92	-	-	16.59	39.52
Sample Size:							
10	10	10	-	7	7	7	-
Mean:							
2760	19.2	2.61	-	220	10.89	2.37	-
Standard Deviation:							
3209.6	23.7	.71	-	120.5	2.36	.19	-
Variability Factor:							
-	3.70	-	-	-	1.53	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

$$MSB = SSB/(k-1)$$

$$MSW = SSW/(N-k)$$

Example 2 (Continued)

$F = MSB/MSW$

where:

k = number of treatment technologies

n_i = number of data points for technology i

N = number of data points for all technologies

T_i = sum of natural logtransformed data points for each technology

X_{ij} = the natural logtransformed observations (j) for treatment technology (i)

$N_1 = 10$, $N_2 = 7$, $N = 17$, $k = 2$, $T_1 = 26.14$, $T_2 = 16.59$, $T = 42.73$, $T^2 = 1825.85$, $T_1^2 = 683.30$,

$T_2^2 = 275.23$

$$SSB = \left(\frac{683.30}{10} + \frac{275.23}{7}\right) - \frac{1825.85}{17} = 0.25$$

$$SSW = (72.92 + 39.52) - \left(\frac{683.30}{10} + \frac{275.23}{7}\right) = 4.79$$

$MSB = 0.25/1 = 0.25$

$MSW = 4.79/15 = 0.32$

$$F = \frac{0.25}{0.32} = 0.78$$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	0.25	0.25	0.78
Within(W)	15	4.79	0.32	

The critical value of the F test at the 0.05 significance level is 4.54. Since the F value is less than the critical value, the means are not significantly different (i.e., they are homogeneous).

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

Example 3
Chlorobenzene

Activated sludge followed by carbon adsorption				Biological treatment			
Influent (µg/l)	Effluent (µg/l)	ln(effluent)	[ln(effluent)]^2	Influent (µg/l)	Effluent (µg/l)	ln(effluent)	ln[(effluent)]^2
7200.00	80.00	4.38	19.18	9206.00	1083.00	6.99	48.86
6500.00	70.00	4.25	18.06	16646.00	709.50	6.56	43.03
6075.00	35.00	3.56	12.67	49775.00	460.00	6.13	37.58
3040.00	10.00	2.30	5.29	14731.00	142.00	4.96	24.60
				3159.00	603.00	6.40	40.96
				6756.00	153.00	5.03	25.30
				3040.00	17.00	2.83	8.01
Sum:							
-	-	14.49	55.20	-	-	38.90	228.34
Sample Size:							
4	4	4	-	7	7	7	-
Mean:							
5703	49	3.62	-	14759	452.5	5.56	-
Standard Deviation:							
1835.4	32.24	.95		16311.86	379.04	1.42	
Variability Factor:							
-	7.00	-	-	-	15.79	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^{\,2}}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

MSB = SSB/(k-1)

MSW = SSW/(N-k)

F = MSB/MSW

Example 3 (Continued)

where,

k = number of treatment technologies

n_i = number of data points for technology i

N = number of data points for all technologies

T_i = sum of natural logtransformed data points for each technology

X_{ij} = the natural logtransformed observations (j) for treatment technology (i)

$N_1 = 4,\ N_2 = 7,\ N = 11,\ k = 2,\ T_1 = 14.49,\ T_2 = 38.90,\ T = 53.39,\ T^2 = 2850.49,\ T_1^2 = 209.96$

$T_2^2 = 1513.21$

$$SSB = \left[\frac{209.96}{4} + \frac{1513.21}{7}\right] - \frac{2850.49}{11} = 9.52$$

$$SSW = (55.20 + 228.34) - \left[\frac{209.96}{4} + \frac{1513.21}{7}\right] = 14.88$$

$MSB = 9.52/1 = 9.52$

$MSW = 14.88/9 = 1.65$

$F = 9.52/1.65 = 5.77$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	9.53	9.53	5.77
Within(W)	9	14.89	1.65	

The critical value of the F test at the 0.05 significance level is 5.12. Since the F value is larger than the critical value, the means are significantly different (i.e., they are heterogeneous). Activated sludge followed by carbon adsorption is "best" in this example because the mean of the long-term performance value, i.e., the effluent concentration, is lower.

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

A.2 Variability Factor

$$VF = \frac{C_{99}}{Mean}$$

where:

VF = estimate of daily maximum variability factor determined from a sample population of daily data;
C_{99} = estimate of performance values for which 99 percent of the daily observations will be below. C_{99} is calculated using the following equation: $C_{99} = Exp(y + 2.33\ Sy)$ where y and Sy are the mean and standard deviation, respectively, of the logtransformed data; and
Mean = average of the individual performance values.

EPA is establishing this figure as an instantaneous maximum because the Agency believes that on a day-to-day basis the waste should meet the applicable treatment standards. In addition, establishing this requirement makes it easier to check compliance on a single day. The 99th percentile is appropriate because it accounts for almost all process variability.

In several cases, all the results from analysis of the residuals from BDAT treatment are found at concentrations less than the detection limit. In such cases, all the actual concentration values are considered unknown and, hence, cannot be used to estimate the variability factor of the analytical results. Below is a description of EPA's approach for calculating the variability factor for such cases with all concentrations below the detection limit.

It has been postulated as a general rule that a lognormal distribution adequately describes the variation among concentrations. Agency data show that the treatment residual concentrations are distributed approximately lognormally. Therefore, the lognormal model has been used routinely in the EPA development of numerous regulations in the Effluent Guidelines program and is being used in the BDAT program. The variability factor (VF) was defined as the ratio of the 99th percentile (C_{99}) of the lognormal distribution to its arithmetic mean (Mean), as follows:

$$VF = \frac{C_{99}}{\text{Mean}}. \qquad (1)$$

The relationship between the parameters of the lognormal distribution and the parameters of the normal distribution created by taking the natural logarithms of the lognormally distributed concentrations can be found in most mathematical statistics texts (see, for example, Distribution in Statistics-Volume 1 by Johnson and Kotz, 1970). The mean of the lognormal distribution can be expressed in terms of the mean (μ) and standard deviation (σ) of the normal distribution as follows:

$$C_{99} = \text{Exp}\ (\mu + 2.33\sigma) \qquad (2)$$

$$\text{Mean} = \text{Exp}\ (\mu + 0.5\sigma^2). \qquad (3)$$

By substituting (2) and (3) in (1), the variability factor can then be expressed in terms of σ as follows:

$$VF = \text{Exp}\ (2.33\ \sigma - 0.5\sigma^2). \qquad (4)$$

For residuals with concentrations that are not all below the detection limit, the 99th percentile and the mean can be estimated from the actual analytical data and, accordingly, the variability factor (VF) can be estimated using equation (1). For residuals with concentrations that are below the detection limit, the above equations can be used in conjunction with the following assumptions to develop a variability factor.

- Assumption 1: The actual concentrations follow a lognormal distribution. The upper limit (UL) is equal to the detection limit. The lower limit (LL) is assumed to be equal to one-tenth of the detection limit. This assumption is based on the fact that data from well-designed and well-operated treatment systems generally fall within one order of magnitude.

- Assumption 2: The natural logarithms of the concentrations have a normal distribution with an upper limit equal to ln (UL) and a lower limit equal to ln (LL).

- Assumption 3: The standard deviation (σ) of the normal distribution is approximated by:

  $$\begin{aligned} \sigma &= [\ln(UL) - \ln(LL)] / [(2)(2.33)] \\ &= [\ln(UL/LL)] / 4.66. \end{aligned} \qquad (5)$$

  (Note that when $LL = (0.1)(UL)$ as in Assumption 1, then $\sigma = (\ln 10) / 4.66 = 0.494$.)

Substitution of the σ value from equation (5) into equation (4) yields the variability factor, VF, as shown:

$$VF = 2.8. \qquad (6)$$

APPENDIX B

ANALYTICAL QA/QC

This appendix presents quality assurance/quality control (QA/QC) information for the available performance data presented in Section 3.3 and identifies the methods and procedures used for analyzing the constituents to be regulated. The QA/QC information includes matrix spike recovery data, which are used to adjust the analytical results for accuracy. In general, the adjusted analytical results (referred to as accuracy-corrected concentrations) are used for comparing the performance of one technology to that of another and for calculating treatment standards for those constituents to be regulated.

B.1 Accuracy Correction

The accuracy-corrected concentration for a constituent in a matrix is the analytical result multiplied by the correction factor (the reciprocal of the recovery fraction;* i.e., the correction factor is 100 divided by the percent recovery). For example, if Compound A is measured at 2.55 mg/l and the percent recovery is 85 percent, the accuracy-corrected concentration is 3.00 mg/l:

2.55 mg/l (analytical result)	x	1/0.85 (correction factor)	=	3.00 mg/l (accuracy-corrected concentration)

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* The recovery fraction is the ratio of (1) the measured amount of the constituent in a spiked aliquot minus the measured amount of the constituent in the original unspiked aliquot to (2) the known amount of the constituent added to spike the original aliquot (refer to the Generic Quality Assurance Project Plan for the Land Disposal Restriction Program ("BDAT")).

The appropriate recovery values are selected according to the procedures specified in Section 1.2.6(3).

Tables B-1 and B-2 present matrix spike recovery data for K022 waste. Using these analytical recovery values, the data points were corrected for accuracy. Table B-3 presents recovery data for F006 waste from which the standards for metals in K022 waste were transferred. Table B-4 shows accuracy-corrected concentrations for the F006 treated TCLP data. This table also indicates why data points were deleted from the data base.

B.2 Methods and Procedures Employed to Generate the Data Used in Calculating Treatment Standards

Table B-5 lists the methods used for analyzing the constituents to be regulated in K022 waste. Most of these methods are specified in SW-846 (USEPA 1986a). For some analyses, the SW-846 methods were modified; these modifications are presented in Table B-6. The Agency plans to use these methods and procedures to enforce the treatment standards for K022 waste.

Table B-1 Matrix Spike Recovery Data for Kiln Ash Residuals from Plant 1

Constituent	Sample percent recovery	Duplicate percent recovery
Volatile Organics		
1,1-Dichloroethane	77	77
Trichloroethene	89	87
Chlorobenzene	101	100
Toluene	106	110
Benzene	102	104
(Average of volatiles)	(95)	(95.6)
Semivolatile Organics (acid extractable)		
Pentachlorophenol	14 [a]	18 [a]
Phenol	53	51
2-Chlorophenol	47	48
4-Chloro-3-methylphenol	30	34
4-Nitrophenol	13 [a]	12 [a]
(Average of acid extractables)	(43.3)	(44.3)
Semivolatile Organics (base/neutral extractable)		
1,2,4-Trichlorobenzene	74	71
Acenaphthene	40	43
2,4-Dinitrotoluene	60	63
Pyrene	14 [a]	18 [a]
N-Nitroso-di-n-propylamine	74	73
1,4-Dichlorobenzene	76	76
(Average of base/neutral extractables)	(64.8)	(65.2)

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[a] These data are not acceptable for use in developing treatment standards because the percent recovery is less than 20 percent.

Reference: USEPA 1988a.

Table B-2 Matrix Spike Recovery Data for Kiln Ash Residuals from Plant 2

Constituent	Sample percent recovery	Duplicate percent recovery
Volatile Organics		
1,1-Dichloroethane	88	90
Trichloroethene	76	80
Chlorobenzene	102	104
Toluene	104	100
Benzene	102	104
(Average of volatiles)	(94.5)	(95.6)
Semivolatile Organics (acid extractable)		
Pentachlorophenol	NA	NA
Phenol	NA	NA
2-Chlorophenol	NA	NA
4-Chloro-3-methylphenol	NA	NA
4-Nitrophenol	NA	NA
(Average of acid extractables)	(NA)	(NA)
Semivolatile Organics (base/neutral extractable)		
1,2,4-Trichlorobenzene	NA	NA
Acenaphthene	NA	NA
2,4-Dinitrotoluene	NA	NA
Pyrene	NA	NA
N-Nitroso-di-n-propylamine	NA	NA
1,4-Dichlorobenzene	NA	NA
(Average of base/neutral extractables)	(NA)	(NA)

NA = Not available.

Reference: USEPA 1988b.

Table B-3 Matrix Spike Recovery Data for the TCLP Extracts from Stabilization of F006 Waste

Constituent	Original amount found (ppm)	Duplicate (ppm)	% Error	Actual spike	% Recovery	Accuracy-correction factor
Arsenic	0.101[a]	0.01	0.0	0.086	94.5	1.06
	0.01[b]	0.01	0.0	0.068	104	0.96
Barium	0.3737[a]	0.3326	5.82	4.9474	91.9	1.09
	0.2765[b]	0.222	10.9	5.1462	97.9	1.02
Cadmium	0.0075[a]	0.0069	4.17	4.9010	97.9	1.02
	2.9034[b]	0.7555	58.7	6.5448	94.3	1.06
Chromium	0.3494[a]	0.4226	9.48	4.6780	85.8	1.17
	0.2213[b]	0.2653	9.0	4.5709	86.6	1.15
Copper	0.2247[a]	0.2211	0.81	4.8494	92.5	1.08
	0.1526[b]	0.1462	2.14	4.9981	97.0	1.03
Lead	0.3226[a]	0.3091	2.14	4.9619	92.9	1.08
	0.2142[b]	0.2287	3.27	4.6930	89.4	1.12
Mercury	0.001[a]	0.001	0.0	0.0034	92	1.09
	0.001[b]	0.001	0.0	0.0045	110	0.91
Nickel	0.028[a]	0.0264	6.87	4.5400	90.3	1.11
	0.4742[b]	0.0859	69.3	4.6093	86.6	1.15
Selenium[c]	0.101[a]	0.12	8.6	0.175	86	1.16
	0.043[b]	0.053	10.4	0.095	66[d]	0.96
Silver[c]	0.0437[a]	0.0399	4.55	4.2837	84.8	1.18
	0.0344[b]	0.0411	8.87	0.081	0.87[d]	114.9
Zinc	0.0133[a]	0.0238	28.3	5.0910	101.4	0.99
	27.202[b]	3.65	76.3	19.818	87.8	1.14

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[a] At a mix ratio of 0.5.

[b] At a mix ratio of 0.2.

[c] For a mix ratio of 0.2, correction factors of 1.16 and 1.18 were used when correcting for selenium and silver concentrations, respectively.

[d] This value is not considered in the calculation for the accuracy-correction factor.

Reference: Memo to R. Turner, U.S. EPA/HWERL, from Jesse R. Conner, Chemical Waste Management, dated January 20, 1988.

Table B-4 Accuracy-Corrected Performance Data for Stabilization of F006 Waste

Constituent	Stream	Concentration (ppm) Sample Set #								
		1	2	3	4	5	6	7	8	9
Arsenic	Untreated total	-	-	-	-	-	-	-	-	-
	Untreated TCLP	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	0.88
	Treated TCLP^{a}	$<0.01^{d}$	$<0.01^{c,d}$	$<0.01^{c,d}$	$<0.01^{c,d}$	$<0.01^{c,d}$	$<0.01^{c,d}$	$<0.01^{c,d}$	$<0.01^{c,d}$	$<0.02^{c,d}$
	Treated TCLP^{b}	-	$<0.01^{d}$	$<0.01^{d}$	$<0.01^{d}$	$<0.01^{d}$	$<0.01^{d}$	$<0.01^{d}$	$<0.01^{d}$	$<0.02^{d}$
Barium	Untreated total	36.4	21.6	85.5	17.2	14.3	24.5	12.6	15.3	19.2
	Untreated TCLP	0.08	0.32	1.41	0.84	0.38	0.07	0.04	0.53	0.28
	Treated TCLP^{a}	0.12^{f}	0.51^{c}	0.34	0.20^{c}	0.32^{c}	0.31^{c}	0.04^{c}	0.33^{c}	0.19^{c}
	Treated TCLP^{b}	-	0.46^{f}	0.34^{c}	0.25	0.21	0.36^{f}	0.15^{f}	0.29	0.09
Cadmium	Untreated total	1.3	31.3	67.3	1.30	720	7.28	5.39	5.81	5.04
	Untreated TCLP	0.01	2.21	1.13	0.22	23.6	0.3	0.06	0.18	0.01
	Treated TCLP^{a}	0.01^{e}	0.53^{c}	0.06	0.01^{c}	3.43^{c}	0.02^{c}	0.01^{c}	0.01^{c}	$<0.01^{c}$
	Treated TCLP^{b}	-	0.01	0.02^{c}	0.01	0.01	0.01	0.01	0.01	$<0.01^{e}$
Chromium	Untreated total	1270	755	716	110	12200	3100	42900	47.9	644
	Untreated TCLP	0.34	0.76	0.43	0.18	25.3	38.7	360	0.04	0.01
	Treated TCLP^{a}	0.59^{f}	0.46^{c}	0.09	0.27^{c}	0.29^{c}	0.24^{c}	3.5^{c}	0.11^{c}	0.03^{c}
	Treated TCLP^{b}	-	0.45	0.23^{c}	0.35^{f}	0.44	0.88	1.41	0.23^{f}	0.23^{e}
Copper	Untreated total	40.2	7030	693	1510	160	1220	10600	17600	27400
	Untreated TCLP	0.15	368	1.33	4.6	1.14	31.7	8.69	483	16.9
	Treated TCLP^{a}	0.20^{f}	5.57^{c}	1.69^{f}	0.31^{c}	0.21^{c}	0.22^{c}	0.41^{c}	0.52^{c}	3.28^{c}
	Treated TCLP^{b}	-	0.27	1.99^{c}	0.29	0.31	0.22	0.45	0.34	0.50
Lead	Untreated total	35.5	409	25.7	88.5	52	113	156	169	24500
	Untreated TCLP	0.26	10.7	0.26	0.45	0.45	3.37	1.0	4.22	50.2
	Treated TCLP^{a}	0.33^{f}	0.45^{c}	0.34^{f}	0.34^{c}	0.27^{c}	0.34^{c}	0.34^{c}	0.35^{c}	2.67^{c}
	Treated TCLP^{b}	-	0.39	0.44^{c}	0.37^{g}	0.39^{g}	0.39	0.41	0.40	0.29

Table B-4 (Continued)

Constituent	Stream	Concentration (ppm) Sample Set # 1	2	3	4	5	6	7	8	9
Mercury	Untreated total	-	-	-	-	-	-	-	-	-
	Untreated TCLP	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001
	Treated TCLP[a]	<0.001[d]	<0.001[c,d]	<0.001[d]	<0.001[c,d]	<0.001[c,d]	<0.001[c,d]	<0.001[c,d]	<0.001[c,d]	<0.001[c,d]
	Treated TCLP[b]	-	<0.001[d]	<0.001[c,d]	<0.001[d]	<0.001[d]	<0.001[d]	<0.001[d]	<0.001[d]	<0.001[d]
Nickel	Untreated total	435	989	259	37	701	19400	13000	23700	5730
	Untreated TCLP	0.71	22.7	1.1	0.52	9.78	730	152	644	16.1
	Treated TCLP[a]	0.05	1.73[c]	0.26	0.12[c]	0.61[c]	19.1[c]	0.46[c]	18.1[c]	1.25[c]
	Treated TCLP[b]	-	0.03	0.17[c]	0.02	0.04	0.06	0.11	0.04	0.02
Selenium	Untreated total	-	-	-	-	-	-	-	-	-
	Untreated TCLP	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.45
	Treated TCLP[a]	0.07[d]	0.07[c,d]	0.08[d]	0.09[c,d]	0.05[c,d]	0.06[c,d]	0.05[c,d]	0.08[c,d]	<0.01[c,d]
	Treated TCLP[b]	-	0.13[d]	0.13[c,d]	0.16[d]	0.10[d]	0.13[d]	0.08[d]	0.08[d]	<0.01[d]
Silver	Untreated total	2.3	6.62	39	9.05	5.28	4.08	12.5	8.11	19.1
	Untreated TCLP	0.01	0.14	0.02	0.16	0.08	0.12	0.05	0.31	<0.01
	Treated TCLP[a]	0.04[e]	0.04[c]	0.24[f]	0.04[c]	0.05[c]	0.04[c]	0.04[c]	0.04[c]	<0.01[c]
	Treated TCLP[b]	-	0.06	0.06[c]	0.05	0.07[g]	0.06	0.06[f]	0.06	<0.01[e]
Zinc	Untreated total	1560	4020	631	90200	35900	27800	120	15700	322
	Untreated TCLP	0.16	219	5.41	2030	867	1200	0.62	650	1.29
	Treated TCLP[a]	0.03	42.0[c]	0.06	36[c]	3.87[c]	42.0[c]	0.02[c]	5.17[c]	0.08[c]
	Treated TCLP[b]	-	0.01	0.03[c]	0.04	0.03	0.04	0.02	0.02	<0.01

---

[a] Mix ratio is 0.2. The mix ratio is the ratio of the reagent weight to waste weight.

[b] Mix ratio is 0.5.

Note: Data points were deleted for the reasons given in the following footnotes:

[c] Less effective design and operation.

[d] No untreated total concentration or TCLP.

[e] Untreated TCLP value low.

[f] Treated values greater than untreated value.

[g] Reduction attributed to dilution with reagent.

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Table B-5. Analytical Methods for Regulated Constituents Analysis

Analysis/Methods	Method	Reference
Semivolatile Organics:		
Continuous liquid-liquid extraction	3520	1
Soxhlet extraction	3540	1
Gas chromatography/mass spectrometry for semivolatile organics: Capillary Column Technique	8270	1
Volatile Organics:		
Purge and trap	5030	1
Gas chromatography/mass spectrometry for volatile organics	8240	1
Metals:		
Digestion		
All solids	3050	1
Inductively coupled plasma atomic emission spectroscopy (chromium and nickel)	6010	1
Sulfide	9030	1
TCLP	51 FR 40643	2

References:

1. USEPA. 1986a. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. _Test methods for evaluating solid waste_ SW-846, 3rd ed. November 1986.

2. USEPA. 1986b. U.S. Environmental Protection Agency, Office of Solid Waste. Hazardous waste management systems; land disposal restrictions; final rule; Appendix I to Part 268 - Toxicity Characteristic Leaching Procedure (TCLP). 51 FR 40643-40654. November 7, 1986.

Table B-6 Method Modifications Used to Analyze K022
Untreated and Treated Samples

Method modifications

Volatile Organics

In the volatiles analyses, methanol extractions of the samples were performed, with the methanol extract ultimately diluted into the actual purging water. Surrogate and matrix spikes were added at the extraction stage. In general, 1,000-fold and greater dilutions were required in the volatiles analyses. This level allowed major list constituents to be characterized and effected some control over late eluting hydrocarbons that might tend to foul the system.

Semivolatile Organics

Because of the high hydrocarbon nature of the matrix, some modifications were necessary in the semivolatile preparation procedure. The samples were originally extracted (pitch) or diluted (oil and raw waste) from approximately 1 gram to 5 milliliters in an attempt to achieve as low a detection limit as possible. However, further dilution was found to be necessary before quantitative work was possible; the sample extract was dark and highly concentrated. The modification made was that additional surrogates and matrix spikes were added prior to the further dilution in order that they might be measurable in the final aliquot. Accounting was made for any spikes already present. In general, 25-fold and greater dilutions were required in the semivolatiles analyses.

APPENDIX C

DETECTION LIMITS FOR TESTED WASTES

Appendix C contains the detection limits for the untreated waste and treated residual for Plants 1 and 2. Table C-1 contains the detection limits for the untreated waste for Plant 1. Table C-2 contains the detection limits for the kiln ash for Plant 1. Table C-3 contains the detection limits for the untreated waste and the kiln ash for Plant 2.

Table C-1 Detection Limits of BDAT List Constituents in K022 Untreated Waste for Plant 1

BDAT reference no.	Constituent	Untreated waste[a]					
		R-1 (mg/kg)	R-2 (mg/kg)	R-3 (mg/kg)	R-4 (mg/kg)	R-5 (mg/kg)	R-6 (mg/kg)
	Volatile Organics						
222.	Acetone						
1.	Acetonitrile						
2.	Acrolein						
3.	Acrylonitrile						
4.	Benzene						
5.	Bromodichloromethane						
6.	Bromomethane						
223.	n-Butyl alcohol						
7.	Carbon tetrachloride						
8.	Carbon disulfide						
9.	Chlorobenzene						
10.	2-Chloro-1,3-butadiene						
11.	Chlorodibromomethane						
12.	Chloroethane						
13.	2-Chloroethyl vinyl ether						
14.	Chloroform						
15.	Chloromethane						
16.	3-Chloropropene						
17.	1,2-Dibromo-3-chloropropane						
18.	1,2-Dibromoethane						
19.	Dibromomethane						
20.	trans-1,4-Dichloro-2-butene						
21.	Dichlorodifluoromethane						
22.	1,1-Dichloroethane						
23.	1,2-Dichloroethane						
24.	1,1-Dichloroethylene						
25.	trans-1,2-Dichloroethene						
26.	1,2-Dichloropropane						
27.	trans-1,3-Dichloropropene						
28.	cis-1,3-Dichloropropene						
29.	1,4-Dioxane						
224.	2-Ethoxyethanol						
225.	Ethyl acetate						
226.	Ethyl benzene						
30.	Ethyl cyanide						
227.	Ethyl ether						
31.	Ethyl methacrylate						
214.	Ethylene oxide						
32.	Iodomethane						

[a] Detection limits for the untreated waste are RCRA Confidential Business Information (CBI).

Table C-1 (Continued)

BDAT reference no.	Constituent	Untreated waste[a] R-1 (mg/kg)	R-2 (mg/kg)	R-3 (mg/kg)	R-4 (mg/kg)	R-5 (mg/kg)	R-6 (mg/kg)
	Volatile Organics (continued)						
33.	Isobutyl alcohol						
228.	Methanol						
34.	Methyl ethyl ketone						
229.	Methyl isobutyl ketone						
35.	Methyl methacrylate						
37.	Methacrylonitrile						
38.	Methylene chloride						
230.	2-Nitropropane						
39.	Pyridine						
40.	1,1,1,2-Tetrachloroethane						
41.	1,1,2,2-Tetrachloroethane						
42.	Tetrachloroethene						
43.	Toluene						
44.	Tribromomethane						
45.	1,1,1-Trichloroethane						
46.	1,1,2-Trichloroethane						
47.	Trichloroethene						
48.	Trichloromonofluoromethane						
49.	1,2,3-Trichloropropane						
231.	1,1,2-Trichloro-1,2,2-trifluoroethane						
50.	Vinyl chloride						
215.	1,2-Xylene						
216.	1,3-Xylene						
217.	1,4-Xylene						
	Semivolatiles						
51.	Acenaphthalene						
52.	Acenaphthene						
53.	Acetophenone						
54.	2-Acetylaminofluorene						
55.	4-Aminobiphenyl						
56.	Aniline						
57.	Anthracene						
58.	Aramite						
59.	Benz(a)anthracene						
218.	Benzal chloride						
60.	Benzenethiol						
61.	Deleted						
62.	Benzo(a)pyrene						

[a] Detection limits for the untreated waste are RCRA Confidential Business Information (CBI).

Table C-1 (Continued)

BDAT reference no.	Constituent	Untreated waste[a]					
		R-1 (mg/kg)	R-2 (mg/kg)	R-3 (mg/kg)	R-4 (mg/kg)	R-5 (mg/kg)	R-6 (mg/kg)
	Semivolatile Organics (continued)						
63.	Benzo(b)fluoranthene						
64.	Benzo(ghi)perylene						
65.	Benzo(k)fluoranthene						
66.	p-Benzoquinone						
67.	Bis(2-chloroethoxy)methane						
68.	Bis(2-chloroethyl)ether						
69.	Bis(2-chloroisopropyl)ether						
70.	Bis(2-ethylhexyl)phthalate						
71.	4-Bromophenyl phenyl ether						
72.	Butyl benzyl phthalate						
73.	2-sec-Butyl-4,6-dinitrophenol						
74.	p-Chloroaniline						
75.	Chlorobenzilate						
76.	p-Chloro-m-cresol						
77.	2-Chloronaphthalene						
78.	2-Chlorophenol						
79.	3-Chloropropionitrile						
80.	Chrysene						
81.	ortho-Cresol						
82.	para-Cresol						
232.	Cyclohexanone						
83.	Dibenz(a,h)anthracene						
84.	Dibenzo(a,e)pyrene						
85.	Dibenzo(a,i)pyrene						
86.	m-Dichlorobenzene						
87.	o-Dichlorobenzene						
88.	p-Dichlorobenzene						
89.	3,3'-Dichlorobenzidine						
90.	2,4-Dichlorophenol						
91.	2,6-Dichlorophenol						
92.	Diethyl phthalate						
93.	3,3'-Dimethoxybenzidine						
94.	p-Dimethylaminoazobenzene						
95.	3,3'-Dimethylbenzidine						
96.	2,4-Dimethylphenol						
97.	Dimethyl phthalate						
98.	Di-n-butyl phthalate						
99.	1,4-Dinitrobenzene						
100.	4,6-Dinitro-o-cresol						
101.	2,4-Dinitrophenol						

[a] Detection limits for the untreated waste are RCRA Confidential Business Information (CBI).

Table C-1 (Continued)

BDAT reference no.	Constituent	Untreated waste[a] R-1 (mg/kg)	R-2 (mg/kg)	R-3 (mg/kg)	R-4 (mg/kg)	R-5 (mg/kg)	R-6 (mg/kg)
	Semivolatile Organics (continued)						
102.	2,4-Dinitrotoluene						
103.	2,6-Dinitrotoluene						
104.	Di-n-octyl phthalate						
105.	Di-n-propylnitrosamine						
106.	Diphenylamine						
219.	Diphenylnitrosamine						
107.	1,2-Diphenylhydrazine						
108.	Fluoranthene						
109.	Fluorene						
110.	Hexachlorobenzene						
111.	Hexachlorobutadiene						
112.	Hexachlorocyclopentadiene						
113.	Hexachloroethane						
114.	Hexachlorophene						
115.	Hexachloropropene						
116.	Indeno(1,2,3-cd)pyrene						
117.	Isosafrole						
118.	Methapyrilene						
119.	3-Methylcholanthrene						
120.	4,4'-Methylenebis (2-chloroaniline)						
36.	Methyl methanesulfonate						
121.	Naphthalene						
122.	1,4-Naphthoquinone						
123.	1-Naphthylamine						
124.	2-Naphthylamine						
125.	p-Nitroaniline						
126.	Nitrobenzene						
127.	4-Nitrophenol						
128.	N-Nitrosodi-n-butylamine						
129.	N-Nitrosodiethylamine						
130.	N-Nitrosodimethylamine						
131.	N-Nitrosomethylethylamine						
132.	N-Nitrosomorpholine						
133.	N-Nitrosopiperidine						
134.	n-Nitrosopyrrolidine						
135.	5-Nitro-o-toluidine						
136.	Pentachlorobenzene						
137.	Pentachloroethane						
138.	Pentachloronitrobenzene						

[a] Detection limits for the untreated waste are RCRA Confidential Business Information (CBI).

Table C-1 (Continued)

BDAT reference no.	Constituent	Untreated waste[a]					
		R-1 (mg/kg)	R-2 (mg/kg)	R-3 (mg/kg)	R-4 (mg/kg)	R-5 (mg/kg)	R-6 (mg/kg)
	Semivolatile Organics (continued)						
139.	Pentachlorophenol						
140.	Phenacetin						
141.	Phenanthrene						
142.	Phenol						
220.	Phthalic anhydride						
143.	2-Picoline						
144.	Pronamide						
145.	Pyrene						
146.	Resorcinol						
147.	Safrole						
148.	1,2,4,5-Tetrachlorobenzene						
149.	2,3,4,6-Tetrachlorophenol						
150.	1,2,4-Trichlorobenzene						
151.	2,4,5-Trichlorophenol						
152.	2,4,6-Trichlorophenol						
153.	Tris(2,3-dibromopropyl) phosphate						
	Metals						
154.	Antimony						
155.	Arsenic						
156.	Barium						
157.	Beryllium						
158.	Cadmium						
159.	Chromium (total)						
221.	Chromium (hexavalent)						
160.	Copper						
161.	Lead						
162.	Mercury						
163.	Nickel						
164.	Selenium						
165.	Silver						
166.	Thallium						
167.	Vanadium						
168.	Zinc						
	Inorganics						
169.	Cyanide						
170.	Fluoride						
171.	Sulfide						

[a] Detection limits for the untreated waste are RCRA Confidential Business Information (CBI).

Table C-1 (Continued)

BDAT reference no.	Constituent	Untreated waste[a]					
		R-1 (mg/kg)	R-2 (mg/kg)	R-3 (mg/kg)	R-4 (mg/kg)	R-5 (mg/kg)	R-6 (mg/kg)
	Organochlorine pesticides						
172.	Aldrin						
173.	alpha-BHC						
174.	beta-BHC						
175.	delta-BHC						
176.	gamma-BHC						
177.	Chlordane						
178.	DDD						
179.	DDE						
180.	DDT						
181.	Dieldrin						
182.	Endosulfan I						
183.	Endosulfan II						
184.	Endrin						
185.	Endrin aldehyde						
186.	Heptachlor						
187.	Heptachlor epoxide						
188.	Isodrin						
189.	Kepone						
190.	Methoxyclor						
191.	Toxaphene						
	Phenoxyacetic acid herbicides						
192.	2,4-Dichlorophenoxyacetic acid						
193.	Silvex						
194.	2,4,5-T						
	Organophosphorous insecticides						
195.	Disulfoton						
196.	Famphur						
197.	Methyl parathion						
198.	Parathion						
199.	Phorate						
	PCBs						
200.	Aroclor 1016						
201.	Aroclor 1221						
202.	Aroclor 1232						

[a] Detection limits for the untreated waste are RCRA Confidential Business Information (CBI).

Table C-1 (Continued)

BDAT reference no.	Constituent	Untreated waste[a]					
		R-1 (mg/kg)	R-2 (mg/kg)	R-3 (mg/kg)	R-4 (mg/kg)	R-5 (mg/kg)	R-6 (mg/kg)
	PCBs (continued)						
203.	Aroclor 1242						
204.	Aroclor 1248						
205.	Aroclor 1254						
206.	Aroclor 1260						
	Dioxins and furans						
207.	Hexachlorodibenzo-p-dioxins						
208.	Hexachlorodibenzofurans						
209.	Pentachlorodibenzo-p-dioxins						
210.	Pentachlorodibenzofurans						
211.	Tetrachlorodibenzo-p-dioxins						
212.	Tetrachlorodibenzofurans						
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin						

[a] Detection limits for the untreated waste are RCRA Confidential Business Information (CBI).

ND = Not detected.
D = Detected.
NA = Not analyzed.

Table C-2 Detection Limits of BDAT List Constituents in Kiln Ash for Plant 1

BDAT reference no.	Constituent	A-1 (mg/kg)	A-2 (mg/kg)	A-3 (mg/kg)	A-4 (mg/kg)	A-5 (mg/kg)	A-6 (mg/kg)
	Volatiles Organics						
222.	Acetone	NA	NA	NA	NA	NA	NA
1.	Acetonitrile	0.420	0.420	0.420	0.420	0.420	0.420
2.	Acrolein	0.065	0.065	0.065	0.065	0.065	0.065
3.	Acrylonitrile	0.0375	0.0375	0.0375	0.0375	0.0375	0.0375
4.	Benzene	0.014	0.014	0.014	0.014	0.014	0.014
5.	Bromodichloromethane	0.0125	0.0135	0.0125	0.0125	0.0125	0.0125
6.	Bromomethane	0.046	0.046	0.046	0.046	0.046	0.046
223.	n-Butyl alcohol	NA	NA	NA	NA	NA	NA
7.	Carbon tetrachloride	0.016	0.016	0.016	0.016	0.016	0.016
8.	Carbon disulfide	0.006	0.006	0.006	0.006	0.006	0.006
9.	Chlorobenzene	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115
10.	2-Chloro-1,3-butadiene	0.006	0.006	0.006	0.006	0.006	0.006
11.	Chlorodibromomethane	0.0145	0.0145	0.0145	0.0145	0.0145	0.0145
12.	Chloroethane	0.0345	0.0345	0.0345	0.0345	0.0345	0.0345
13.	2-Chloroethyl vinyl ether	0.020	0.020	0.020	0.020	0.020	0.020
14.	Chloroform	0.0115	0.0115	0.015	0.0115	0.0115	0.0115
15.	Chloromethane	0.0375	0.0375	0.0375	0.0375	0.0375	0.0375
16.	3-Chloropropene	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
17.	1,2-Dibromo-3-chloropropane	0.025	0.025	0.025	0.025	0.025	0.025
18.	1,2-Dibromoethane	0.020	0.020	0.020	0.020	0.020	0.020
19.	Dibromomethane	0.017	0.017	0.017	0.017	0.017	0.017
20.	trans-1,4-Dichloro-2-butene	0.090	0.909	0.090	0.090	0.090	0.090
21.	Dichlorodifluoromethane	0.235	0.235	0.235	0.235	0.235	0.235
22.	1,1-Dichloroethane	0.0155	0.0155	0.0155	0.0155	0.0155	0.0155
23.	1,2-Dichloroethane	0.0135	0.0135	0.0135	0.0135	0.0135	0.0135
24.	1,1-Dichloroethylene	0.011	0.011	0.011	0.011	0.011	0.011
25.	trans-1,2-Dichloroethene	0.010	0.010	0.010	0.010	0.010	0.010
26.	1,2-Dichloropropane	0.015	0.015	0.015	0.0150	0.015	0.015
27.	trans-1,3-Dichloropropene	0.0145	0.0145	0.0145	0.0145	0.0145	0.0145
28.	cis-1,3-Dichloropropene	0.0135	0.0135	0.0135	0.0135	0.0135	0.0135
29.	1,4-Dioxane	0.500	0.500	0.500	0.500	0.500	0.500
224.	2-Ethoxyethanol	NA	NA	NA	NA	NA	NA
225.	Ethyl acetate	NA	NA	NA	NA	NA	NA
226.	Ethyl benzene	NA	NA	NA	NA	NA	NA
30.	Ethyl cyanide	1.50	1.50	1.50	1.50	1.50	1.50
227.	Ethyl ether	NA	NA	NA	NA	NA	NA
31.	Ethyl methacrylate	0.500	0.500	0.500	0.500	0.500	0.500
214.	Ethylene oxide	NA	NA	NA	NA	NA	NA
32.	Iodomethane	0.0465	0.0465	0.0465	0.0465	0.0465	0.0465

Table C-2 (Continued)

BDAT reference no.	Constituent	A-1 (mg/kg)	A-2 (mg/kg)	A-3 (mg/kg)	A-4 (mg/kg)	A-5 (mg/kg)	A-6 (mg/kg)
	Volatile organics (continued)						
33.	Isobutyl alcohol	1.0	1.0	1.0	1.0	1.0	1.0
228.	Methanol	NA	NA	NA	NA	NA	NA
34.	Methyl ethyl ketone	0.0225	0.0225	0.0225	0.0225	0.0225	0.0225
229.	Methyl isobutyl ketone	NA	NA	NA	NA	NA	NA
35.	Methyl methacrylate	0.5	0.5	0.5	0.5	0.5	0.5
37.	Methacrylonitrile	1.15	1.15	1.15	1.15	1.15	1.15
38.	Methylene chloride	0.008	0.008	0.008	0.008	0.008	0.008
230.	2-Nitropropane	NA	NA	NA	NA	NA	NA
39.	Pyridine	0.5	0.5	0.5	0.5	0.5	0.5
40.	1,1,1,2-Tetrachloroethane	0.018	0.108	0.108	0.018	0.018	0.018
41.	1,1,2,2-Tetrachloroethane	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115
42.	Tetrachloroethene	0.017	0.017	0.017	0.017	0.017	0.017
43.	Toluene	0.012	0.012	0.012	0.012	0.012	0.012
44.	Tribromomethane	0.0135	0.0135	0.0135	0.0135	0.0135	0.0135
45.	1,1,1-Trichloroethane	0.013	0.013	0.013	0.013	0.013	0.013
46.	1,1,2-Trichloroethane	0.0115	0.0115	0.0115	0.0115	0.0115	0.0115
47.	Trichloroethene	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125
48.	Trichloromonofluoromethane	0.0295	0.0295	0.0295	0.0295	0.0295	0.0295
49.	1,2,3-Trichloropropane	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385
231.	1,1,2-Trichloro-1,2,2-trifluoroethane	NA	NA	NA	NA	NA	NA
50.	Vinyl chloride	0.0395	0.0395	0.0395	0.0395	0.0395	0.0395
215.	1,2-Xylene	NA	NA	NA	NA	NA	NA
216.	1,3-Xylene	NA	NA	NA	NA	NA	NA
217.	1,4-Xylene	NA	NA	NA	NA	NA	NA
	Semivolatiles						
51.	Acenaphthalene	3.02	6.04	2.96	2.96	2.94	2.96
52.	Acenaphthene	1.51	3.02	1.48	1.48	1.47	1.48
53.	Acetophenone	3.80	7.60	3.76	3.76	3.724	3.76
54.	2-Acetylaminofluorene	4.20	8.40	4.16	4.16	4.116	4.16
55.	4-Aminobiphenyl	1.30	2.60	1.29	1.29	1.274	1.29
56.	Aniline	6.00	12.00	5.94	5.94	5.88	5.94
57.	Anthracene	1.10	2.20	1.09	1.09	1.078	1.09
58.	Aramite	3.10	6.20	3.07	3.07	3.038	3.07
59.	Benz(a)anthracene	0.80	1.60	0.79	0.79	0.784	0.79
218.	Benzal chloride	NA	NA	NA	NA	NA	NA
60.	Benzenethiol	210	420	207.9	207.9	205.8	207.9
61.	Deleted	NA	NA	NA	NA	NA	NA
62.	Benzo(a)pyrene	3.50	7.00	3.46	3.46	3.43	3.46

Table C-2 (Continued)

BOAT reference no.	Constituent	A-1 (mg/kg)	A-2 (mg/kg)	A-3 (mg/kg)	A-4 (mg/kg)	A-5 (mg/kg)	A-6 (mg/kg)
	Semivolatile organics (Continued)						
63.	Benzo(b)fluoranthene	3.85	7.70	3.81	3.81	3.773	3.81
64.	Benzo(ghi)perylene	2.30	4.60	2.28	2.28	2.254	2.28
65.	Benzo(k)fluoranthene	1.45	2.90	1.44	1.44	1.421	1.44
66.	p-Benzoquinone	18.49	36.99	18.31	18.31	18.13	18.31
67.	Bis(2-chloroethoxy)methane	0.60	1.2	0.59	0.59	0.588	0.59
68.	Bis(2-chloroethyl)ether	2.05	4.10	2.03	2.03	2.009	2.03
69.	Bis(2-chloroisopropyl)ether	2.50	5.00	2.47	2.47	2.45	2.47
70.	Bis(2-ethylhexyl)phthalate	2.79	5.59	2.77	2.77	2.74	2.77
71.	4-Bromophenyl phenyl ether	2.65	5.30	2.63	2.63	2.6	2.63
72.	Butyl benzyl phthalate	3.20	6.41	3.17	3.17	3.14	3.17
73.	2-sec-Butyl-4,6-dinitrophenol	5.25	10.51	5.20	5.20	5.15	5.20
74.	p-Chloroaniline	2.50	5.00	2.47	2.47	2.45	2.47
75.	Chlorobenzilate	2.90	5.80	2.87	2.87	2.842	2.87
76.	p-Chloro-m-cresol	5.50	11.00	5.44	5.44	5.39	5.44
77.	2-Chloronaphthalene	1.50	3.00	1.48	1.48	1.47	1.48
78.	2-Chlorophenol	1.58	3.16	1.57	1.57	1.55	1.57
79.	3-Chloropropionitrile	5.00	10.00	4.95	4.95	4.9	4.95
80.	Chrysene	2.40	4.79	2.37	2.37	2.35	2.37
81.	ortho-Cresol	2.45	4.90	2.42	2.42	2.4	2.42
82.	para-Cresol	2.45	4.90	2.42	2.42	2.4	2.42
232	Cyclohexanone	NA	NA	NA	NA	NA	NA
83.	Dibenzo(a,h)anthracene	4.10	8.20	4.06	4.06	4.02	4.06
84.	Dibenzo(a,e)pyrene	3.75	7.51	3.72	3.72	3.68	3.72
85.	Dibenzo(a,i)pyrene	4.50	9.00	4.45	4.45	4.41	4.45
86.	m-Dichlorobenzene	1.65	3.30	1.64	1.64	1.62	1.64
87.	o-Dichlorobenzene	1.65	3.30	1.64	1.64	1.62	1.64
88.	p-Dichlorobenzene	1.65	3.30	1.64	1.64	1.62	1.64
89.	3,3'-Dichlorobenzidine	5.50	11.00	5.44	5.44	5.39	5.44
90.	2,4-Dichlorophenol	11.73	23.46	11.62	11.62	11.5	11.62
91.	2,6-Dichlorophenol	2.24	4.49	2.22	2.22	2.2	2.22
92.	Diethyl phthalate	1.30	2.59	1.28	1.28	1.27	1.28
93.	3,3'-Dimethoxybenzidine	90	180	89.08	89.08	88.2	89.08
94.	p-Dimethylaminoazobenzene	7.50	14.99	7.42	7.42	7.35	7.42
95.	3,3'-Dimethylbenzidine	12.5	25.1	12.42	12.42	12.3	12.42
96.	2,4-Dimethylphenol	0.50	1.00	0.49	0.49	0.49	0.49
97.	Dimethyl phthalate	2.05	4.10	2.03	2.03	2.01	2.03
98.	Di-n-butyl phthalate	4.40	8.79	4.35	4.35	4.31	4.35
99.	1,4-Dinitrobenzene	2.50	5.00	2.47	2.47	2.45	2.47
100.	4,6-Dinitro-o-cresol	1.35	2.69	1.33	1.33	1.32	1.33
101.	2,4-Dinitrophenol	1.55	3.10	1.54	1.54	1.52	1.54

Table C-2 (Continued)

BDAT reference no.	Constituent	A-1 (mg/kg)	A-2 (mg/kg)	A-3 (mg/kg)	A-4 (mg/kg)	A-5 (mg/kg)	A-6 (mg/kg)
	Semivolatile organics (Continued)						
102	2,4-Dinitrotoluene	8.39	16.79	8.31	8.31	8.23	8.31
103.	2,6-Dinitrotoluene	-	-	-	-	-	-
104.	Di-n-octyl phthalate	2.79	5.59	2.77	2.77	2.74	2.77
105.	Di-n-propylnitrosamine	1.90	3.79	1.88	1.88	1.86	1.88
106.	Diphenylamine	2.65	5.30	2.63	2.63	2.6	2.63
219.	Diphenylnitrosamine	2.65	5.30	2.63	2.63	2.6	2.63
107.	1,2-Diphenylhydrazine	3.45	6.90	3.41	3.41	3.38	3.41
108.	Fluoranthene	3.00	6.00	2.97	2.97	2.94	2.97
109.	Fluorene	1.55	3.10	1.54	1.54	1.52	1.54
110.	Hexachlorobenzene	3.40	6.79	3.36	3.36	3.33	3.36
111.	Hexachlorobutadiene	1.55	3.10	1.54	1.54	1.52	1.54
112.	Hexachlorocyclopentadiene	1.45	2.90	1.43	1.43	1.42	1.43
113.	Hexachloroethane	0.80	1.59	0.79	0.79	0.78	0.79
114.	Hexachlorophene	-	-	-	-	-	-
115.	Hexachloropropene	7.00	13.99	6.93	6.93	6.86	6.93
116.	Indeno(1,2,3-cd)pyrene	2.95	5.90	2.92	2.92	2.89	2.92
117.	Isosafrole	2.20	4.41	2.18	2.18	2.16	2.18
118.	Methapyrilene	11.53	23.05	11.41	11.41	11.3	11.41
119.	3-Methylcholanthrene	6.50	13.0	6.43	6.43	6.37	6.43
120.	4,4'-Methylenebis (2-chloroaniline)	35	70	34.64	34.64	34.3	34.64
36.	Methyl methanesulfonate	-	-	-	-	-	-
121.	Naphthalene	0.55	1.10	0.54	0.54	0.539	0.54
122.	1,4-Naphthoquinone	0.5	1	0.49	0.49	0.49	0.49
123.	1-Naphthylamine	36	72	35.65	35.65	35.3	35.65
124.	2-Naphthylamine	50	100	49.5	49.5	49	49.5
125.	p-Nitroaniline	4.15	8.30	4.11	4.11	4.07	4.11
126.	Nitrobenzene	5.50	11.00	5.44	5.44	5.39	5.44
127.	4-Nitrophenol	3.35	6.69	3.31	3.31	3.28	3.31
128.	N-Nitrosodi-n-butylamine	6	12	5.94	5.94	5.88	5.94
129.	N-Nitrosodiethylamine	1	2	1	1	0.98	1
130.	N-Nitrosodimethylamine	8.50	17	8.41	8.41	8.33	8.41
131.	N-Nitrosomethylethylamine	1.85	3.69	1.3	1.3	1.81	1.3
132.	N-Nitrosomorpholine	0.85	1.70	0.84	0.84	0.833	0.84
133.	N-Nitrosopiperidine	2.00	4.00	1.98	1.98	1.96	1.98
134.	n-Nitrosopyrrolidine	1.50	3.00	1.48	1.48	1.47	1.48
135.	5-Nitro-o-toluidine	4.55	9	4.50	4.50	4.46	4.50
136.	Pentachlorobenzene	4.7	9.4	4.65	4.65	4.6	4.65
137.	Pentachloroethane	0.80	1.60	0.79	0.79	0.784	0.79
138.	Pentachloronitrobenzene	4.75	9.51	4.71	4.71	4.66	4.71

Table C-2 (Continued)

BDAT reference no.	Constituent	A-1 (mg/kg)	A-2 (mg/kg)	A-3 (mg/kg)	A-4 (mg/kg)	A-5 (mg/kg)	A-6 (mg/kg)
	Semivolatile organics (Continued)						
139.	Pentachlorophenol	1.85	3.69	1.83	1.83	1.81	1.83
140.	Phenacetin	4.7	9.4	4.65	4.65	4.6	4.65
141.	Phenanthrene	2.50	5.00	2.47	2.47	2.45	2.47
142.	Phenol	1.9	3.8	1.88	1.88	1.86	1.88
220.	Phthalic anhydride	NA	NA	NA	NA	NA	NA
143.	2-Picoline	18.5	36.9	18.28	18.28	18.1	18.28
144.	Pronamide	11.5	23	11.41	11.41	11.3	11.41
145.	Pyrene	2.3	4.59	2.27	2.27	2.25	2.27
146.	Resorcinol	38.5	76.9	38.01	38.01	37.7	38.01
147.	Safrole	2.4	4.79	2.37	2.37	2.35	2.37
148.	1,2,4,5-Tetrachlorobenzene	3.2	6.41	3.17	3.17	3.14	3.17
149.	2,3,4,6-Tetrachlorophenol	15.5	31.1	15.35	15.35	15.2	15.35
150.	1,2,4-Trichlorobenzene	0.95	1.90	0.94	0.94	0.931	0.94
151.	2,4,5-Trichlorophenol	1.10	2.20	1.09	1.09	1.08	1.09
152.	2,4,6-Trichlorophenol	1.65	3.30	1.64	1.64	1.62	1.64
153.	Tris(2,3-dibromopropyl) phosphate	4.70	9.40	4.70	4.70	4.61	4.66
	Metals						
154.	Antimony	15	15	15	15	15	15
155.	Arsenic	15	15	15	15	15	15
156.	Barium	1	1	1	1	1	1
157.	Beryllium	0.05	0.05	0.5	0.05	0.05	0.05
158.	Cadmium	2.5	2.5	2.5	2.5	2.5	2.5
159.	Chromium (total)	5	5	5	5	5	5
221.	Chromium (hexavalent)	NA	NA	NA	NA	NA	NA
160.	Copper	5	5	5	5	5	5
161.	Lead	15	15	15	15	15	15
162.	Mercury	0.5	0.5	0.5	0.5	0.5	0.5
163.	Nickel	10	10	10	10	10	10
164.	Selenium	30	30	30	30	30	30
165.	Silver	2.5	2.5	2.5	2.5	2.5	2.5
166.	Thallium	15	15	15	15	15	15
167.	Vanadium	5	5	5	5	5	5
168.	Zinc	2.5	2.5	2.5	2.5	2.5	2.5
	Metals TCLP[a]						
	Arsenic	0.15	0.015	0.015	0.015	0.015	0.015
	Barium	0.01	0.01	0.01	0.01	0.01	0.01

Table C-2 (Continued)

BDAT reference no.	Constituent	A-1 (mg/kg)	A-2 (mg/kg)	A-3 (mg/kg)	A-4 (mg/kg)	A-5 (mg/kg)	A-6 (mg/kg)
	Metals TCLP[a] (continued)						
	Cadmium	0.025	0.025	0.025	0.025	0.025	0.025
	Chromium	0.025	0.025	0.025	0.025	0.025	0.025
	Lead	0.15	0.15	0.15	0.15	0.15	0.15
	Mercury	0.005	0.005	0.005	0.005	0.005	0.005
	Selenium	0.3	0.3	0.5	0.5	0.5	0.5
	Silver	0.025	0.025	0.025	0.025	0.025	0.025
	Inorganics						
169.	Cyanide	1.25	NA	NA	NA	NA	NA
170.	Fluoride	10	NA	NA	NA	NA	NA
171.	Sulfide	200	NA	NA	NA	NA	NA
	Organochlorine pesticides						
172.	Aldrin	0.4	NA	NA	NA	NA	NA
173.	alpha-BHC	0.4	NA	NA	NA	NA	NA
174.	beta-BHC	0.4	NA	NA	NA	NA	NA
175.	delta-BHC	0.4	NA	NA	NA	NA	NA
176.	gamma-BHC	0.4	NA	NA	NA	NA	NA
177.	Chlordane	0.8	NA	NA	NA	NA	NA
178.	DDD	0.4	NA	NA	NA	NA	NA
179.	DDE	0.4	NA	NA	NA	NA	NA
180.	DDT	0.4	NA	NA	NA	NA	NA
181.	Dieldrin	0.4	NA	NA	NA	NA	NA
182.	Endosulfan I	0.4	NA	NA	NA	NA	NA
183.	Endosulfan II	0.4	NA	NA	NA	NA	NA
184.	Endrin	0.4	NA	NA	NA	NA	NA
185.	Endrin aldehyde	0.8	NA	NA	NA	NA	NA
186.	Heptachlor	0.4	NA	NA	NA	NA	NA
187.	Heptachlor epoxide	0.4	NA	NA	NA	NA	NA
188.	Isodrin	0.4	NA	NA	NA	NA	NA
189.	Kepone	0.4	NA	NA	NA	NA	NA
190.	Methoxyclor	NA	NA	NA	NA	NA	NA
191.	Toxaphene	0.4	NA	NA	NA	NA	NA
	Phenoxyacetic acid herbicides						
192.	2,4-Dichlorophenoxyacetic acid	0.02	NA	NA	NA	NA	NA
193.	Silvex	0.01	NA	NA	NA	NA	NA
194.	2,4,5-T	0.01	NA	NA	NA	NA	NA

Table C-2 (Continued)

BDAT reference no.	Constituent	A-1 (mg/kg)	A-2 (mg/kg)	A-3 (mg/kg)	A-4 (mg/kg)	A-5 (mg/kg)	A-6 (mg/kg)
	Organophosphorous insecticides						
195.	Disulfoton	0.05	NA	NA	NA	NA	NA
196.	Famphur	0.04	NA	NA	NA	NA	NA
197.	Methyl parathion	0.05	NA	NA	NA	NA	NA
198.	Parathion	0.05	NA	NA	NA	NA	NA
199.	Phorate	0.05	NA	NA	NA	NA	NA
	PCBs						
200.	Aroclor 1016	0.8	NA	NA	NA	NA	NA
201.	Aroclor 1221	0.8	NA	NA	NA	NA	NA
202.	Aroclor 1232	0.8	NA	NA	NA	NA	NA
203.	Aroclor 1242	0.8	NA	NA	NA	NA	NA
204.	Aroclor 1248	0.8	NA	NA	NA	NA	NA
205.	Aroclor 1254	0.8	NA	NA	NA	NA	NA
206.	Aroclor 1260	0.8	NA	NA	NA	NA	NA
	Dioxins and furans						
207.	Hexachlorodibenzo-p-dioxins	0.00007	NA	NA	NA	NA	NA
208.	Hexachlorodibenzofurans	-	NA	NA	NA	NA	NA
209.	Pentachlorodibenzo-p-dioxins	0.0002	NA	NA	NA	NA	NA
210.	Pentachlorodibenzofurans	0.000068	NA	NA	NA	NA	NA
211.	Tetrachlorodibenzo-p-dioxins	0.000022	NA	NA	NA	NA	NA
212.	Tetrachlorodibenzofurans	0.000028	NA	NA	NA	NA	NA
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin	0.00036	NA	NA	NA	NA	NA

- = No detection limit specified. Detection limit studies have not been completed.

NA = Not analyzed

[a] Units are mg/l.

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Table C-3 Detection Limits of BDAT List Constituents Analyzed in K022 Waste from Plant 2

BDAT reference no	Constituent	CAS no.	Detection limit (mg/kg) Untreated waste[a]	 Ash residual[b]
	Volatiles			
222.	Acetone	67-64-1		NA
1.	Acetonitrile	75-05-8		0.42
2.	Acrolein	107-02-8		0.065
3.	Acrylonitrile	107-13-1		0.0375
4.	Benzene	71-43-2		0.014
5.	Bromodichloromethane	75-27-4		0.0125
6.	Bromomethane	74-83-9		0.046
223.	n-Butyl alcohol	71-36-3		NA
7.	Carbon tetrachloride	56-23-5		0.016
8.	Carbon disulfide	75-15-0		0.006
9.	Chlorobenzene	108-90-7		0.0115
10.	2-Chloro-1,3-butadiene	126-99-8		0.006
11.	Chlorodibromomethane	124-48-1		0.0145
12.	Chloroethane	75-00-3		0.0345
13.	2-Chloroethyl vinyl ether	110-75-8		0.02
14.	Chloroform	67-66-3		0.0115
15.	Chloromethane	74-87-3		0.0375
16.	3-Chloropropene	107-05-1		0.0025
17.	1,2-Dibromo-3-chloropropane	96-12-8		0.025
18.	1,2-Dibromoethane	106-93-4		0.02
19.	Dibromomethane	74-95-3		0.017
20.	trans-1,4-Dichloro-2-butene	110-57-6		0.09
21.	Dichlorodifluoromethane	75-71-8		0.235
22.	1,1-Dichloroethane	75-34-3		0.0155
23.	1,2-Dichloroethane	107-06-2		0.0135
24.	1,1-Dichloroethylene	75-35-4		0.011
25.	trans-1,2-Dichloroethene	156-60-5		0.01
26.	1,2-Dichloropropane	78-87-5		0.015
27.	trans-1,3-Dichloropropene	10061-02-6		0.0145
28.	cis-1,3-Dichloropropene	10061-01-5		0.0135
29.	1,4-Dioxane	123-91-1		0.5
224.	2-Ethoxyethanol	110-80-5		NA
225.	Ethyl acetate	141-78-6		NA
226.	Ethyl benzene	100-41-4		NA
30.	Ethyl cyanide	107-12-0		1.5
227.	Ethyl ether	60-29-7		NA
31.	Ethyl methacrylate	97-63-2		0.5

Table C-3 (Continued)

BDAT reference no.	Constituent	CAS no.	Detection limit (mg/kg) Untreated waste[a]	Detection limit (mg/kg) Ash residual[b]
	Volatiles			
214.	Ethylene oxide	75-21-8		NA
32.	Iodomethane	74-88-4		0.0465
33.	Isobutyl alcohol	78-83-1		1.0
228.	Methanol	67-56-1		NA
34.	Methyl ethyl ketone	78-93-3		0.0225
229.	Methyl isobutyl ketone	108-10-1		NA
35.	Methyl methacrylate	80-62-6		0.5
37.	Methacrylonitrile	126-98-7		1.15
38.	Methylene chloride	75-09-2		0.008
230.	2-Nitropropane	79-46-9		NA
39.	Pyridine	110-86-1		0.5
40.	1,1,1,2-Tetrachloroethane	630-20-6		0.018
41.	1,1,2,2-Tetrachloroethane	79-34-6		0.115
42.	Tetrachloroethene	127-18-4		0.017
43.	Toluene	108-88-3		0.012
44.	Tribromomethane	75-25-2		0.0135
45.	1,1,1-Trichloroethane	71-55-6		0.013
46.	1,1,2-Trichloroethane	79-00-5		0.0115
47.	Trichloroethene	79-01-6		0.0125
48.	Trichloromonofluoromethane	75-69-4		0.0295
49.	1,2,3-Trichloropropane	96-18-4		0.0385
231.	1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1		NA
50.	Vinyl chloride	75-01-4		0.0395
215.	1,2-Xylene	97-47-6		NA
216.	1,3-Xylene	108-38-3		NA
217.	1,4-Xylene	106-44-5		NA
	Semivolatiles			
51.	Acenaphthalene	208-96-8		0.99
52.	Acenaphthene	83-32-9		0.495
53.	Acetophenone	96-86-2		1.254
54.	2-Acetylaminofluorene	53-96-3		1.396
55.	4-Aminobiphenyl	92-67-1		0.429
56.	Aniline	62-53-3		1.98
57.	Anthracene	120-12-7		0.363
58.	Aramite	140-57-8		1.023
59.	Benz(a)anthracene	56-55-3		0.264
218.	Benzal chloride	98-87-3		NA
60.	Benzenethiol	108-98-5		69.3

Table C-3 (Continued)

BDAT reference no.	Constituent	CAS no.	Detection limit (mg/kg) Untreated waste[a]	Detection limit (mg/kg) Ash residual[b]
	Semivolatiles (continued)			
61.	Deleted			-
62.	Benzo(a)pyrene	50-32-8		1.155
63.	Benzo(b)fluoranthene	205-99-2		1.271
64.	Benzo(ghi)perylene	191-24-2		0.759
65.	Benzo(k)fluoranthene	207-08-9		0.479
66.	p-Benzoquinone	106-51-4		6.105
67.	Bis(2-chloroethoxy)methane	111-91-1		0.196
68.	Bis(2-chloroethyl)ether	111-44-4		0.677
69.	Bis(2-chloroisopropyl)ether	39638-32-9		0.625
70.	Bis(2-ethylhexyl)phthalate	117-81-7		0.924
71.	4-Bromophenyl phenyl ether	101-55-3		0.875
72.	Butyl benzyl phthalate	85-68-7		1.056
73.	2-sec-Butyl-4,6-dinitrophenol	88-85-7		1.733
74.	p-Chloroaniline	106-47-8		0.825
75.	Chlorobenzilate	510-15-6		0.957
76.	p-Chloro-m-cresol	59-50-7		1.815
77.	2-Chloronaphthalene	91-58-7		0.495
78.	2-Chlorophenol	95-57-8		0.611
79.	3-Chloropropionitrile	542-76-7		1.650
80.	Chrysene	218-01-9		0.792
81.	ortho-Cresol	95-48-7		0.809
82.	para-Cresol	106-44-5		0.809
232.	Cyclohexanone	108-94-1		NA
83.	Dibenz(a,h)anthracene	53-70-3		1.353
84.	Dibenzo(a,e)pyrene	192-65-4		1.238
85.	Dibenzo(a,i)pyrene	189-55-9		1.485
86.	m-Dichlorobenzene	541-73-1		0.545
87.	o-Dichlorobenzene	95-50-1		0.545
88.	p-Dichlorobenzene	106-46-7		0.545
89.	3,3'-Dichlorobenzidine	91-94-1		1.815
90.	2,4-Dichlorophenol	120-83-2		0.561
91.	2,6-Dichlorophenol	87-65-0		0.743
92.	Diethyl phthalate	84-66-2		0.429
93.	3,3'-Dimethoxybenzidine	119-90-4		29.7
94.	p-Dimethylaminoazobenzene	60-11-7		2.475
95.	3,3'-Dimethylbenzidine	119-93-7		4.125
96.	2,4-Dimethylphenol	105-67-9		0.165
97.	Dimethyl phthalate	131-11-3		0.677
98.	Di-n-butyl phthalate	84-74-2		1.452
99.	1,4-Dinitrobenzene	100-25-4		0.825

Table C-3 (Continued)

BDAT reference no.	Constituent	CAS no.	Detection limit (mg/kg) Untreated waste[a]	Detection limit (mg/kg) Ash residual[b]
	Semivolatiles (continued)			
100.	4,6-Dinitro-o-cresol	534-52-1		0.446
101.	2,4-Dinitrophenol	51-28-5		0.512
102.	2,4-Dinitrotoluene	121-14-2		2.792
103.	2,6-Dinitrotoluene	606-20-2		-
104.	Di-n-octyl phthalate	117-84-0		0.924
105.	Di-n-propylnitrosamine	621-64-7		0.627
106./219.	Diphenylamine/ Diphenylnitrosamine	122-39-4/ 86-30-6		0.675
107.	1,2-Diphenylhydrazine	122-66-7		1.139
108.	Fluoranthene	206-44-0		0.990
109.	Fluorene	86-73-7		0.512
110.	Hexachlorobenzene	118-74-1		1.122
111.	Hexachlorobutadiene	87-68-3		0.512
112.	Hexachlorocyclopentadiene	77-47-4		0.479
113.	Hexachloroethane	67-72-1		0.264
114.	Hexachlorophene	70-30-4		-
115.	Hexachloropropene	1888-71-7		2.310
116.	Indeno(1,2,3-cd)pyrene	193-39-5		0.974
117.	Isosafrole	120-58-1		0.726
118.	Methapyrilene	91-80-5		3.795
119.	3-Methylcholanthrene	56-49-5		2.145
120.	4,4'-Methylenebis (2-chloroaniline)	101-14-4		11.55
36.	Methyl methanesulfonate	66-27-3		-
121.	Naphthalene	91-20-3		0.182
122.	1,4-Naphthoquinone	130-15-4		0.165
123.	1-Naphthylamine	134-32-7		11.68
124.	2-Naphthylamine	91-59-8		16.5
125.	p-Nitroaniline	100-01-6		1.37
126.	Nitrobenzene	98-95-3		0.162
127.	4-Nitrophenol	100-02-7		1.106
128.	N-Nitrosodi-n-butylamine	924-16-3		1.98
129.	N-Nitrosodiethylamine	55-18-5		0.33
130.	N-Nitrosodimethylamine	62-75-9		2.805
131.	N-Nitrosomethylethylamine	10595-95-6		0.61
132.	N-Nitrosomorpholine	59-89-2		0.281
133.	N-Nitrosopiperidine	100-75-4		0.66
134.	n-Nitrosopyrrolidine	930-55-2		0.495
135.	5-Nitro-o-toluidine	99-65-8		1.502

Table C-3 (Continued)

BDAT reference no.	Constituent	CAS no.	Detection limit (mg/kg) Untreated waste[a]	Detection limit (mg/kg) Ash residual[b]
	Semivolatiles (continued)			
136.	Pentachlorobenzene	608-93-5		1.551
137.	Pentachloroethane	76-01-7		0.264
138.	Pentachloronitrobenzene	82-68-8		1.566
139.	Pentachlorophenol	87-86-5		0.611
140.	Phenacetin	62-44-2		1.551
141.	Phenanthrene	85-01-8		0.625
142.	Phenol	108-95-2		0.627
220.	Phthalic anhydride	85-44-9		NA
143.	2-Picoline	109-06-8		6.105
144.	Pronamide	23950-58-5		3.795
145.	Pyrene	129-00-0		0.759
146.	Resorcinol	108-46-3		12.705
147.	Safrole	94-59-7		0.792
148.	1,2,4,5-Tetrachlorobenzene	95-94-3		1.056
149.	2,3,4,6-Tetrachlorophenol	58-90-2		0.512
150.	1,2,4-Trichlorobenzene	120-82-1		0.314
151.	2,4,5-Trichlorophenol	95-95-4		0.363
152.	2,4,6-Trichlorophenol	88-06-2		0.545
153.	Tris(2,3-dibromopropyl) phosphate	126-72-7		15.51
	Metals			
154.	Antimony	7440-36-0		15
155.	Arsenic	7440-38-2		15
156.	Barium	7440-39-3		1
157.	Beryllium	7440-41-7		0.5
158.	Cadmium	7440-43-9		2.5
159.	Chromium (total)	7440-47-32		5
221.	Chromium (hexavalent)	-		NA
160.	Copper	7440-50-8		5
161.	Lead	7439-92-1		15
162.	Mercury	7439-97-6		1
163.	Nickel	7440-02-0		10
164.	Selenium	7782-49-2		30
165.	Silver	7440-22-4		2.5
166.	Thallium	7440-28-0		15
167.	Vanadium	7440-62-2		5
168.	Zinc	7440-66-6		2.5

Table C-3 (Continued)

BDAT reference no.	Constituent	CAS no.	Detection limit (mg/kg) Untreated waste[a]	Detection limit (mg/kg) Ash residual[b]
	Metals TCLP[c]			
	Arsenic			0.15
	Barium			0.01
	Cadmium			0.025
	Chromium			0.025
	Lead			0.15
	Mercury			0.005
	Selenium			0.3
	Silver			0.025
	Inorganics			
169.	Cyanide	57-12-5		2.5
170.	Fluoride	16984-48-8		-
171.	Sulfide	8496-25-8		-
	Organochlorine pesticides			
172.	Aldrin	309-00-2		0.4
173.	alpha-BHC	319-84-6		0.4
174.	beta-BHC	319-85-7		0.4
175.	delta-BHC	319-86-8		0.4
176.	gamma-BHC	58-89-9		0.4
177.	Chlordane	57-74-9		0.4
178.	DDD	72-54-8		0.4
179.	DDE	72-55-9		0.4
180.	DDT	50-29-3		0.4
181.	Dieldrin	60-57-1		0.4
182.	Endosulfan I	939-98-8		0.4
183.	Endosulfan II	33213-6-5		0.4
184.	Endrin	72-20-8		0.4
185.	Endrin aldehyde	7421-93-4		0.8
186.	Heptachlor	76-44-8		0.4
187.	Heptachlor epoxide	1024-57-3		0.4
188.	Isodrin	465-73-6		0.4
189.	Kepone	143-50-0		0.4
190.	Methoxychlor	72-43-5		0.4
191.	Toxaphene	8001-35-2		0.4

Table C-3 (Continued)

BDAT reference no.	Constituent	CAS no.	Detection limit (mg/kg)	
			Untreated waste[a]	Ash residual[b]
	Phenoxyacetic acid herbicides			
192.	2,4-Dichlorophenoxyacetic acid	94-75-7		0.01
193.	Silvex	93-72-1		0.01
194.	2,4,5-T	93-76-5		0.01
	Organophosphorous insecticides			
195.	Disulfoton	298-04-4		0.05
196.	Famphur	52-85-7		0.05
197.	Methyl parathion	298-00-0		0.5
198.	Parathion	56-38-2		0.05
199.	Phorate	298-02-2		0.05
	PCBs			
200.	Aroclor 1016	12674-11-2		0.4
201.	Aroclor 1221	11104-28-2		0.4
202.	Aroclor 1232	11141-16-5		0.4
203.	Aroclor 1242	53469-21-9		0.4
204.	Aroclor 1248	12672-29-6		0.4
205.	Aroclor 1254	11097-69-1		0.4
206.	Aroclor 1260	11096-82-5		0.4
	Dioxins and furans			
207.	Hexachlorodibenzo-p-dioxins			0.000053
208.	Hexachlorodibenzofurans			0.000036
209.	Pentachlorodibenzo-p-dioxins			0.000052
210.	Pentachlorodibenzofurans			0.000049
211.	Tetrachlorodibenzo-p-dioxins			0.000062
212.	Tetrachlorodibenzofurans			0.000062
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6		0.00012

NA = Not analyzed.

- = No detection limit specified. Detection limit studies have not been completed.

[a] Detection limits for the untreated waste are RCRA Confidential Business Information (CBI).

[b] Six ash samples were analyzed for volatile organics. The detection limits listed are applicable for five of the six samples. For one sample, the detection limits are five times higher.

[c] = Units are mg/l.

APPENDIX D

METHOD OF MEASUREMENT FOR THERMAL CONDUCTIVITY

The comparative method of measuring thermal conductivity has been proposed as an ASTM test method under the name "Guarded, Comparative, Longitudinal Heat Flow Technique." A thermal heat flow circuit is used that is the analog of an electrical circuit with resistances in series. A reference material is chosen to have a thermal conductivity close to that estimated for the sample. Reference standards (also known as heat meters) having the same cross-sectional dimensions as the sample are placed above and below the sample. An upper heater, a lower heater, and a heat sink are added to the "stack" to complete the heat flow circuit. See Figure D-1.

The temperature gradients (analogous to potential differences) along the stack are measured with type K (chromel/alumel) thermocouples placed at known separations. The thermocouples are placed into holes or grooves in the references and also in the sample whenever the sample is thick enough to accommodate them.

For molten samples, pastes, greases, and other materials that must be contained, the material is placed in a cell consisting of a top and bottom of Pyrex 7740 and a containment ring of marinite. The sample is 2 inches in diameter and 0.5 inch thick. Thermocouples are not placed into the sample; rather, the temperatures measured in the Pyrex are extrapolated to give the temperature at the top and bottom surfaces of the sample material. The Pyrex disks also serve as the thermal conductivity reference material.

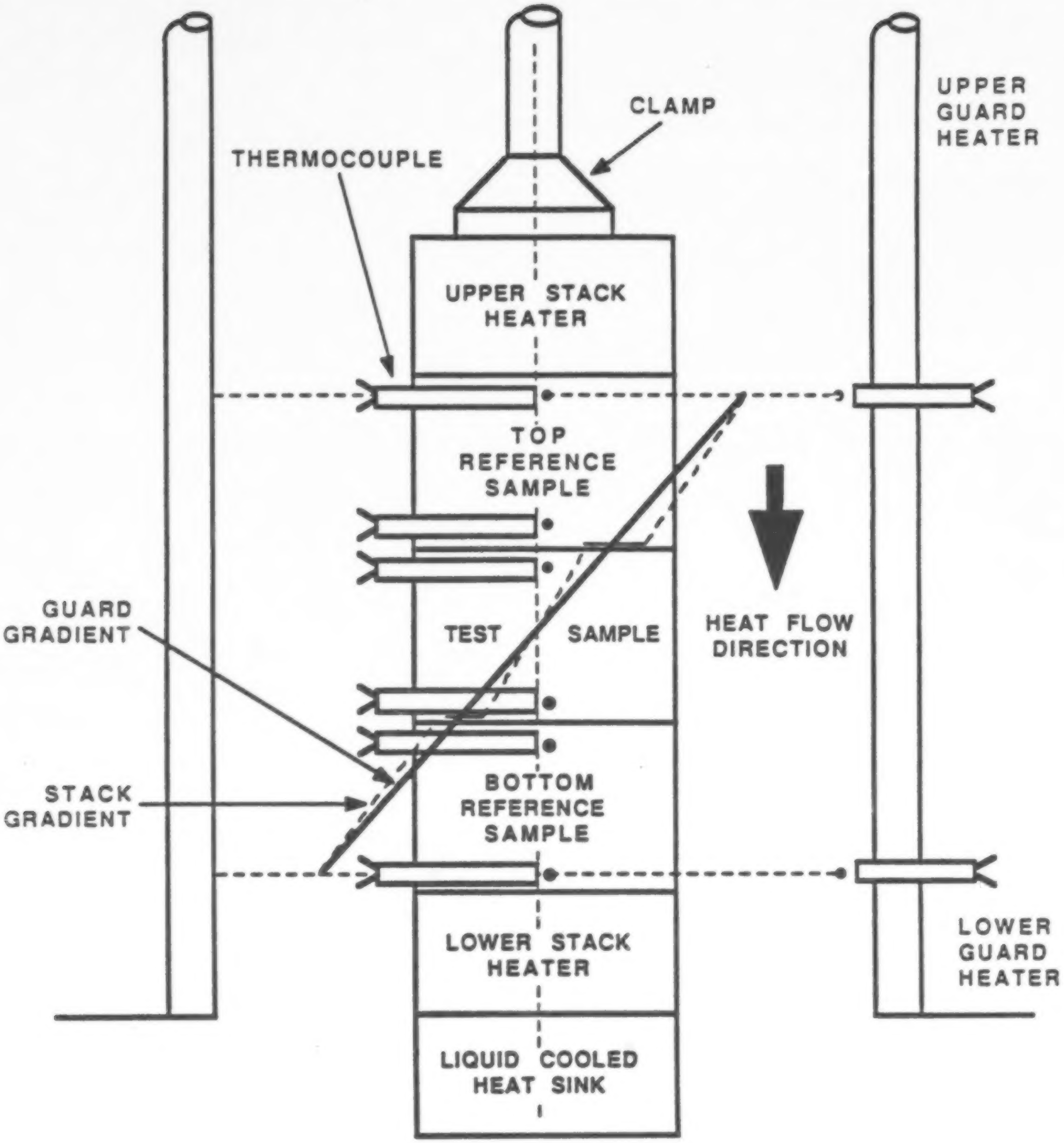

FIGURE D-1 SCHEMATIC DIAGRAM OF THE COMPARATIVE METHOD